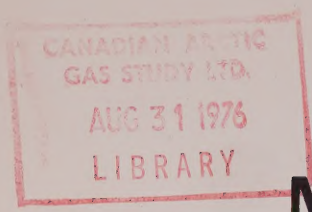


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MACKENZIE DELTA GAS DEVELOPMENT SYSTEM



VOLUME 3

GATHERING SYSTEM AND PRODUCTION OPERATIONS

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MACKENZIE DELTA GAS DEVELOPMENT SYSTEM

VOL. 3

GATHERING SYSTEM AND PRODUCTION OPERATIONS

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I. SUMMARY

The material in this volume is intended to describe proposed gas-handling facilities from the producing wells to the entrance of a process plant. Primarily it involves gathering lines. To construct and operate in the Mackenzie Delta would require a number of field and support facilities such as gas conditioning near the wells, permanent and temporary road transportation, airstrips, docks, a communications network, and automation.

The stage of development differs in various areas. In preparing this volume, the Applicants have attempted to show conceptual and preliminary design methods. As additional wells were drilled and development progressed, changes might occur that would alter the locations and sizes of facilities. For specific illustration the Applicants show the type of facilities required in the Niglintgak, Taglu and Parsons Lake fields.

Gas from the Niglintgak and Taglu fields would be transported to a process plant at Taglu. Gas from areas in the Parsons Lake field would be gathered to a process plant at Parsons Lake. For the conceptual and preliminary engineering designs, it has been assumed that each field would produce at a rate of 500 MMCFD.

The Applicants plan to produce a number of gas wells from each gravel-covered pad or cluster. Single clusters are planned for the Niglintgak and Taglu fields, while three clusters are assumed in Parsons Lake.

Gas would be conditioned, measured and controlled at each cluster before being transported by gathering lines to the process plant.

All well effluent would be moved into the process plant. The hydrate-control system discussed would consist of electrically traced insulated lines supplemented by methanol injection. Other hydrate-control methods might be used depending on development.

Approximately 18 miles of above-ground gathering lines are envisaged. These lines would vary in diameter from 6" to 20" and be supported on piles frozen into the permafrost. Because of the temperature of the gas being produced, construction would be above ground to protect the permafrost from serious degradation. Minor rivers would be crossed by an overhead support system, major rivers by an underground line.

An estimated 3,300,000 yards of gravel would be required for cluster pads, roads, docks, airstrips, accommodation sites and plant locations. Most of it would be obtained from deposits in the Ya Ya and Parsons Lake area.

It is planned to construct and operate the Niglintgak cluster and gathering facilities using winter roads, all-terrain vehicles, and helicopters. At Taglu and Parsons Lake, access to facilities would be mainly by permanent roads. Approximately 10 miles of major and minor roads would be needed, most of this in the Parsons Lake area.

Two permanent air strips are planned - a 2,400-foot STOL strip at Taglu and (tentatively) a 6,500-foot jet strip for the Parsons Lake area. These strips would be built for construction support and would later be used when the two plants were in operation.

Associated Engineering Services Limited were retained by the Applicants to perform conceptual and preliminary design-engineering studies. Most of their efforts were directed toward gathering-system and support-structure analysis. The basic criteria and assumptions they used are summarized on Table I.

It is planned to operate the field facilities and plants by means of an extensive automation and communication system. A continuously manned control centre at each plant would receive analog, alarm and control conditions for all phases of the operation. Operating conditions would automatically be adjusted or shut in as conditions required.

The Applicants have designed the facilities with the primary objectives of safety, efficiency and environmental protection. The reporting procedures that would be followed and the remedial steps that would be taken in the event of an unforeseen upset or mechanical failure are carefully set out.

II. GEOTECHNICAL DATA

A. GENERAL DESCRIPTION

The two major divisions of terrain classification for the Mackenzie Delta System are the low floodplain of the Mackenzie River, typical of the Richards Island location, and the upper gravel-sand hills, typical of the Parsons Lake location. Both areas are within the continuous permafrost zone, with permafrost extending from 0 to 2000 feet.

B. LOWER DELTA

The floodplain terrain consists of fine, fluvial deposits of silt and silty sand occurring in river channels, low-lying plains, low terraces, bordering rivers and alluvial fans. Gravel deposits are few and small, and the floodplains have a thin overlay of organic silt and peat. The over-all relief is flat except for the many channels, meander scars, and thermokarst ponds. The drainage is poorly developed so that the ground surface is generally saturated, with many small lakes and marshy areas. These conditions make for a high ice content in the near-surface soils. Typically, the ground-ice content is medium to high in the top 12 feet. Borehole data from the Richards Island area show a content of stratified or distinctly oriented visible ice ranging from 10 per cent to 70 per cent.

Permafrost in the Taglu area is estimated to be 1800 feet thick, with a talik (unfrozen zone) approximately 200 feet thick starting 200 feet below surface. Surface features show extensive low-centre polygons, and ice wedges.

The ground ice and permafrost make the terrain highly sensitive to disturbances, whether man-induced, such as stripping or compacting of the organic cover, or natural, such as long-term ponding of water or rerouting of flowing water. The resulting degradation takes the form of thermokarst depressions - i.e., subsidence after melting of the ground ice.

Permafrost in the area of the Niglintgak discovery is estimated to be 500-700 feet thick. The immediate area consists of unconsolidated river sediments with little local relief, and is subject to seasonal

flooding. Its proximity to major channels of the Mackenzie river system causes permafrost depths to vary markedly within short distances.

The top 100 feet or so of sediments consist primarily of silt with traces of fine sand. Deeper sediments are primarily sand. The top 15 feet contains more than 25 per cent visible clear-ice lens. The rest of the silt package contains only a small percentage of excess ice in the form of random crystals and inclusions.

The design for foundations and pads, therefore, adopts the philosophy of preventing any thawing of the sensitive, ice-rich, fine-grained soils.

Such fine-grained soils with high ice content constitute poor borrow material, as their high moisture content when thawed makes them unstable. Artificial drying of the silts and silty sands, when either thawed or excavated from unfrozen river channel beds, could improve their properties for fill construction. Coarse-grained fill materials are not available locally and would have to be imported.

C. PARSONS LAKE

The terrain east of Parsons Lake consists of gravel-sand hills, ridges and terraces, with fluvial and glaciofluvial deposits of gravel, sand and silt. The area is also interspersed with old thermokarst lake beds of clay, silt and peat. The sand and gravel deposits vary in thickness, and have thin overlying layers of silt or sand. The relief is generally flat or gently sloping, with shallow channels and low scarps up to 30 feet. Drainage is mainly subsurface, the ground surface being relatively dry except in large flat areas or in channels. Ground ice is therefore typically cement ice only in drained areas, with high segregated ice content in the silt- or peat-filled depressions. Permafrost is estimated to be approximately 2000 feet thick, with unfrozen zones beneath lakes and major river channels.

Well-drained sand and gravel terrain is relatively insensitive to disturbance of the ground surface because the ground-ice content is low. Locally, gully erosion may occur on sloping sites. When thawed, or exposed on a cut slope, the sand and gravel makes reasonably good fill. When it contains more high-ice-content silt and peat, it is not as effective. Thermokarst lake beds should be avoided because of their high content of materials that are unstable when thawed.

Foundation and pad design is based on the prevention of any thawing into the original ground, in case there should be zones of high-ice-content solids. However, where well-drained sands and gravels are known to predominate, some annual thawing may be allowed without the risk of degradation or subsidence - especially in unsurfaced pads and traffic areas, where the subsurface can easily be maintained in the event of minor settlements.

III. WELL-CLUSTER PRODUCING FACILITIES

A. GENERAL DESCRIPTION

1. Introduction

The well clusters would consist of prepared gravel-fill pads to serve three main activities: development drilling, production facilities and support services. The proposed cluster locations are shown in Figure 1.

In all, five clusters are anticipated - one at Niglintgak, one at Taglu, and three at Parsons Lake. The clusters would be about 400 feet wide and up to 2000 feet long, depending on the number of wells. At each cluster wells would be directionally drilled to various parts of the reservoir. The extent to which the cluster approach can be utilized is a function of reservoir depth, because of the physical limitations it imposes on the deviation that can be achieved by directional drilling.

During development drilling, the cluster-pad equipment would include a drilling rig, a sump, a supply depot, fuel storage, living accommodations, a heliport and miscellaneous support equipment. A number of wells would be drilled on the same pad.

After development drilling, production facilities including wellheads, flowlines, manifolds, test modules, control units and flare stack would be designed to fit the well-pad area. The pad size would allow for future compression facilities.

Space would be provided for equipment and personnel to conduct workovers on wells, repairs and maintenance of production equipment. Ancillary support including a communications tower, a small tank farm for chemicals, additives and fuel, and emergency accommodations are also planned.

Figure 2 shows a conceptual plan of a well-cluster producing facility that would accommodate the functions discussed.

2. Pad Design

The terrain is of two general types: the low-lying river-delta deposits in the Niglintgak and Taglu areas, and the rolling, granular hills in the Parsons Lake area. Figure 3 shows a cross-section of the typical pad design for each area.

Insulation would be used to minimize thaw in the pad and thus ensure its stability. Its use would be governed by cost, the quality and availability of the gravel, and the ground conditions. In all cases, the permafrost table would be drawn into the pad itself.

Insulation would probably be styrofoam. Research on other materials, such as wood chips or foamed-in-place sulphur, might develop a more practical system.

A well-cluster pad would contain up to 500,000 cubic yards of fill. The side slopes would be of graded material to ensure slope stability, and would be rip-rapped or sandbagged where necessary for protection against flood waters.

Artificial water ponds created by blocking of natural drainage patterns could adversely affect the stability of the pads. On-site surveys would determine where culverts would be required to insure proper drainage.

Part of the pad itself would be sloped, and enclosed by an impermeable dyke, to contain any spilled fluid.

B. WELLHEAD EQUIPMENT

Each well at the cluster would have a surface and a subsurface (below the permafrost) fail-safe valve. They would be high-low pressure, self-actuated controls with remote overrides, operable from strategic locations and from the Plant Central Control Room. Dual, manually operated master valves would also be provided on the wellheads.

Facilities would be designed to inject methanol into the tubing and flowline automatically. This system would provide hydrate control and would be monitored from the Central Control Room. The methanol would be stored in steel tanks inside an impermeable dyke on the pad site.

The design provides for a corrosion-inhibition system, whereby inhibitor could be injected down the wellbore to protect the tubing and casing, and into the flowline for production-facility and gathering-line protection. The inhibitor would be stored in appropriate steel tankage inside an impermeable dyke on the pad site.

In areas where the wellbores are surrounded by high-ice-content soil or large ice lenses, stability might be maintained by an automatic, temperature-monitored, refrigeration system, whose controls would be monitored at the Central Control Room.

C. FLOWLINES

1. Design

The length of flowline from wellhead to production facilities on the pad would vary from 500 to 2000 feet. Lines would be 6" or 8" in diameter and designed to withstand full shut-in wellhead pressure. Pipe specifications would be the same as outlined in Section IV - Gathering System. Flowline design would be in accordance with CSA standard Z184. Anchor points would be provided near each well and at process modules.

2. Structural Support

All above-grade lines would be supported on pilings frozen into the permafrost and topped with steel superstructures. Figure 4 shows a conceptual support design, which would be similar to those illustrated in Section IV. Wherever movement was required, low-friction sliding bearings would be installed. Full-encirclement sleeves would be used at anchor points.

Support spacing would depend on line size; weight, type and proximity of valves; expansion loops; wellheads, and production facility.

3. Insulation and Heat Tracing

As described in Section IV, flowline insulation and/or heat-tracing capacity might be provided to ensure that minimum design operating temperatures would be maintained to prevent hydrate conditions. Insulation thickness and heat tracing would vary with line size, design specifications, temperature and well effluent.

The pipe-insulation system would be shop-applied, foamed-in-place urethane, covered with a galvanized steel jacket. Flowline joints

would be insulated with pre-formed blocks of urethane and galvanized jackets. For valve surfaces, a shop-applied, spray-on, rigid urethane foam, with a fibreglass epoxy or aluminized tape outer cover, would probably be used.

D. PRODUCING FACILITY

1. Production Routing

Conceptual production-routing flowsheets are shown in Figures 5, 6 and 7. The well effluent, consisting of gas, condensate and free water, would flow to a three-way manifold.

Production rate would be controlled and remotely monitored by a Flow Rate Controller (FRC) located upstream of the manifold. An orifice meter would measure the combined effluent of each well, and the data would be monitored at the process plant. Along with the combined plant-inlet meter, fluctuations in gas rates would be continuously monitored to allow instant plant or controller adjustments as necessary. An automatic high-low pressure-control override would provide the shut-in mechanism to protect the facility against line breaks and emergency shut-ins at the plant. Remote-operated, fail-safe manifold valves, with manual overrides, would route the production one of three ways: group production, test, or flare.

2. Group Production

Production from each well would normally be routed directly through the manifold to the group gathering line, which would be furnished with pigging facilities. The gathering-line inlet would have provision for a gas-compression module to be installed later.

3. Test Facilities

The well-test portion of the production facility would consist of a separator and equipment to meter gas, condensate, and water separately. These fluids would then be combined and routed back to the group production line.

The frequency of well testing would be based on individual well conditions. Production data such as rate, pressure, and temperature reveal information on well behaviour and hydrate conditions, and provide input data for automatic well and plant adjustments. As indicated in Figures 5, 6 and 7, separator relief valves would be tied to flare for emergency relief.

4. Flare System

The flare system at the well cluster could be used during start-up, as a relief during blowdown operations, and as an emergency relief in the event the system should tend to overpressure. A separator would be installed on the flare line to trap liquids so they would not be carried up the stack.

5. Ancillary Facilities

Production facilities would be housed in an insulated shelter. Control for all surface facilities would occupy a separate module, which would also provide emergency accommodations for personnel, supplies, and parts necessary for normal operation and maintenance. Figure 2 shows a typical layout of well-pad facilities including wells, flowlines, production module, control module and tanks.

6. Instrumentation and Safety

Key instrument data would be displayed at each well cluster and at the plant Control Operations Centre. A cable system would relay data to the plants.

Communication links would normally be dualled, to ensure continuous monitoring and contact with operations personnel.

All support vehicles would carry radios. Cable and voice communication would also be provided between each remote well-cluster site and the control room.

Power would probably be supplied from a generating source at the plants. Depending on the length of gathering line, the power would be transmitted by overhead line or through conduit on the gathering-system supports. Emergency standby power would be available at most well-cluster sites.

During testing and initial start-up of the facilities, the operations at the wellsite cluster would be manned as necessary to ensure that the facility was completely "debugged" and would operate with a satisfactory degree of reliability.

Selection of electronic measurement and control equipment would be based on proved performance and reliability.

E. HYDRATE CONTROL

The above-grade gathering lines would be adequately insulated so that, under normal flowing conditions, the gas would not cool to hydrate temperature at line operating pressures.

Electrical heat-tracing of the pipelines would be one method considered for hydrate control during low-flow, shut-down and start-up conditions. The line would be heated to maintain the gas above its hydrate temperature.

Methanol-injection facilities would also be provided at the well cluster. In the case of the Parsons gathering lines, additional provisions might be made along the lines to inject methanol in case it should be necessary to clear a hydrate plug.

Various other alternatives of well-effluent hydrate control are available, such as line heaters, and line insulation with methanol injection. Final selection of the method to be used would be made when conditions were better defined.

F. CONSTRUCTION

1. Scheduling

Construction methods and schedules would be designed to maximize environmental protection and safety in completing the job. Assuming a 1979 start-up, initial selection of construction equipment would be in early 1975, with materials and equipment being moved to sites during the 1976 barge season. On-site activity in the fall of 1976 would consist of gravel stockpiling at the Ya Ya Lake and Parsons Lake pits. Support activities would include camps, fuel storage, and repair facilities.

Movement of gravel to the well-cluster pads would start in January 1976 over winter roads and, if necessary, continue by barge during the summer of 1976 in the Taglu and Niglintgak areas. Summer construction could be maintained in some areas by using permanent roads.

During pad construction, crews would be on site to compact the fill material, construct embankment dykes, place insulation where required, and install piling. This work would be coordinated with other construction activities such as road building, airstrip and dock construction, process-plant site preparation, gathering-system support and line installation, permanent camp installation, and shop and warehouse construction. Scheduling would aim at levelling the work loads, allowing projects to fit the season most suited for that work, ensuring efficient logistical support, and maximizing human safety and environmental protection.

2. Equipment and Material Testing

As far as possible, production and control modules would be built and tested in southern Canada before being barged to the site.

To ensure a safe, reliable operating system, certain field tests would be necessary. They would include inspection of all on-site welds, hydrostatic tests of flowlines after welding, and material tests on pad fill to ensure stability.

3. Manpower

Each individual cluster-construction activity is estimated to require 200 to 250 man months. The work would include building cluster pads, setting piles, installing modules and flowlines, erecting tanks, laying interconnecting piping and control conduit, installing electrical equipment, and tying in support facilities. The manpower requirement for the clusters might peak at 150 men but would average about 50.

4. Accommodations

Construction would be going on in three main areas from mid-1976 through to start-up in 1979.

In the Parsons Lake area, the three well clusters would be connected by all-weather roads. Personnel for pad construction, facility installment, and testing would be based at a central campsite near the plant.

At Taglu, one main construction campsite would handle the various phases of construction for that area. Because of the remoteness of the gravel source at Ya Ya Lake, however, a camp would be needed there as well.

There would be a temporary construction campsite at the Niglintgak well cluster during construction of the pad and associated facilities.

Each camp would have accommodations that would meet the health standards, warehousing and staff adequate to handle incoming materials and supplies, and a shop for repair and maintenance of equipment.

5. Transportation

Construction equipment, supplies and spare parts would be brought in to the work area by barge, boat, aircraft, and conventional vehicles on winter roads. Major equipment for constructing the well-cluster pads, such as bulldozers, trucks, camps and shops, would be taken to the site by barge down the Mackenzie River between June and September. Fuel and supplies would also be moved in for storage and use.

Construction personnel would be transported by aircraft from their residences to the various work sites.

Locally, transportation in summer would be by a combination of barge, boat, helicopter, STOL aircraft, and normal vehicles on all-weather roads. In winter, access to all areas by winter roads, aircraft, or gravel roads would permit the use of conventional equipment. Special equipment such as tracked units, low-tire-pressure units, and hovercraft would be needed only for specific, limited duty to protect the terrain.

G. OPERATIONS AND MAINTENANCE

Under normal operations, remote monitoring and control would be used to assure safe operation and a secure system. Personal surveillance would ensure that remote monitoring and controlling functions operated satisfactorily. Periodic checks (estimated at once a week) plus a routine equipment-operation check would be scheduled. The routine checks would be supplemented by scheduled maintenance and repair of all equipment. A regular weekly inspection might cover the following:

- Communication (power supply, audio check-out)
- Power (frequency, voltage, current)
- Electric operators (activators, switches)
- Electronic controls (card decay, connections)
- Hydraulic, inhibitor, refrigeration and methanol systems
- Standby power
- Fuel storage
- Flow-rate control valve
- Gas, water and condensate meters
- Flare system
- Environmental data such as snow, rain, wind, and water levels in rivers.

Scheduled maintenance and repairs to equipment might be carried out during semi-annual checks as follows:

- Valve operators - disassemble and replace worn parts
- Valves - check and replace worn stems, seats and seals
- Refrigeration unit - check electric motors

- check quality and upgrade refrigerant if necessary.
- check pressure-drop in system for deterioration or plugging
- Pad site
 - check and maintain rip rap
 - level and fill low spots
 - maintain edge embankment
 - apply weed control
- Communication
 - complete check of radio circuits
 - tower guide lines, base security
- Wellheads
 - service valves
 - check annulus for fluid-pressure changes
 - check insulation shelters and repair if deteriorated
- Flowlines
 - check pilings for security, elevation
 - check anchor for stresses

The Applicants would revise and modify maintenance schedules and techniques in the light of system behaviour and operating experience.

IV. GATHERING SYSTEMS

A. GENERAL DESCRIPTION

The gas-gathering systems described herein would transport production from single clusters at Niglintgak and Taglu to the Taglu gas plant, and from three clusters in the Parsons Lake area to the Parsons Lake gas plant. Anticipated gathering-system routes selected from air photos are shown on Figure 1. Detailed field surveys would be required to determine the final line routes. Features of the gathering systems the Applicants plan for use in the three fields are represented schematically in Figures 8 and 9, and described in detail in the following sections.

The gas-gathering lines the Applicants propose for the Mackenzie Delta would transport raw natural gas and small quantities of associated water and liquid hydrocarbons at temperatures ranging up to 150°F. Lines would be run above grade, founded on piles frozen into the permafrost. A minimum clearance of four feet would be provided above grade except in areas subject to seasonal flooding or storm surges, where the minimum clearance would be two feet above the maximum anticipated water levels. Crossings for vehicles and for large animals would be provided along each route. Crossing type and spacing would be selected when the final line routes were determined. The design would provide for full thermal expansion of the exposed line and all line pipe would be thermally insulated to minimize heat losses. Additional measures would be taken to prevent formation of natural-gas hydrates during critical start-up or shut-down operations.

Both above-ground and buried stream crossings would be utilized. The choice of crossing technique would be dictated primarily by the width of the channel and its rating as a navigable or non-navigable waterway.

Lines would be designed to function over a full range of temperatures, from a minimum ambient temperature of -60°F to a maximum process temperature of 150°F. Piping design would conform to the criteria laid down in CSA Standard Z184, "Gas Transmission and Distribution Piping System." Block valves would be installed at intervals of approximately five miles along each line, and the lines would be highly instrumented to permit safe and reliable remote operation. An emergency system would automatically shut in gathering lines in the event of a major line break or an upset downstream of the gathering line.

Sections B through E provide additional data on the design considerations, construction methods, and operating and maintenance techniques the Applicants have developed for gas-gathering lines in the Mackenzie Delta.

B. GATHERING-SYSTEM DESIGN CONCEPTS

1. Route Selection

The Applicants stress that the gathering-system routes illustrated in Figure 1 represent preliminary selections based on air-photo interpretation. Final selection of specific routes could not be made until the precise locations of several of the proposed well clusters were resolved and detailed field surveys of the region carried out.

Final routes would be selected in the light of both engineering and environmental considerations. The choice of gathering-system routes would be based on the following factors:

- a) Minimum use of areas recognized as key habitats for birds and mammals.
- b) A minimum number of stream crossings.
- c) A minimum number of elevation changes (to reduce operating problems with liquid hold-up and slugging).
- d) Elimination of lake crossings, because the non-uniform permafrost conditions in the soils underlying many of the lakes in the Delta might cause problems with support foundations.
- e) The bypassing, wherever possible, of areas sensitive to even minor changes in the permafrost thermal regime.
- f) Avoidance, wherever possible, of low-level flood plains susceptible to inundation by seasonal river floods and/or storm surges generated by summer storms in the Beaufort Sea.
- g) The shortest possible gathering lines.

2. Pipeline Hydraulics

The Applicants have carried out preliminary hydraulic analyses of the proposed gathering systems, based on approximate volume, composition, and flowing pressure and temperature data for the three gas accumulations at Taglu, Parsons Lake and Niglintgak. From the preliminary analyses the following line sizes were selected for further design studies:

<u>System Segment</u>	<u>Nominal Outside Diameter (inches)</u>
Niglintgak - Taglu Plant	20
Taglu - Taglu Plant (individual lines)	6
Parsons Lake Clusters C, E - Plant	16
Parsons Lake Cluster D - Plant	12

The Applicants stress that these line sizes are preliminary selections only. Final sizes would be decided when the locations of several of the well clusters, the gas compositions, and the line throughputs were established. The selection would make due provision for two-phase flow phenomena, possible liquid hold-up and slugging problems, and operation of the gathering system later when flowing pressures had declined.

3. Insulation and Hydrate Control

a) Design Considerations

The Applicants recognize the wide spectrum of weather conditions under which the proposed gathering system would have to operate, and have investigated several alternative methods of hydrate control as means of dealing with anticipated operating problems. The operating conditions considered in selecting a hydrate-control method were mainly:

- Gas-temperature profiles at steady-state flow.
- Gas-temperature profiles during start-up and shut-down.
- Gas-temperature profiles during throughput adjustments (particularly reductions in flow rate).

To arrive at a satisfactory means of operating the gas-gathering lines, the following measures were evaluated both individually and in combination:

- Thermal insulation, to limit the rate of heat transfer from the gathering line.
- Line heaters located at strategic points along the line to maintain temperature.
- A chemical inhibitor, to depress the hydrate-formation temperature of the gas.
- An electrical heat-tracing system, to maintain the temperature of the gas above the level at which hydrates form.

Hydrate-formation curves were calculated for each of the raw gas streams, and used to assess the above hydrate-control measures.

An obvious but essential requirement for operating a warm gas-gathering system in permafrost terrain is enough external insulation and/or refrigeration to prevent permafrost degradation.

b) Heat-Loss Modelling

The effects of insulation on the rate of heat loss were investigated, with prolonged extreme conditions of -60°F temperature and 30 MPH wind speed being assumed. The investigations indicated that insulation alone would limit the temperature drops in the gathering systems proposed by

the Applicants sufficiently to prevent hydrates from forming in the various line segments during steady-state flow. However, alternative means would be needed for the non-steady-state conditions noted in 3.a. The above conditions are considered extreme and unlikely to be encountered for any significant length of time. The investigations also revealed that the insulation thicknesses selected to satisfy the heat-loss requirements imposed by prolonged 30 MPH winds would also withstand for several hours the cooling effects of wind gusts to 80 MPH. The heat capacity of the pipeline fluid, plus the insulation thickness envisaged by the Applicants, would limit the heat-transfer rate to the extent that the stronger gusts would produce no significant extra cooling of the gas stream until after several hours.

The insulating properties used in the heat-loss calculations are summarized in Section IV C.2.

c) Hydrate Control during Start-Up and Shut-Down Operations

Investigations revealed that the extreme operating conditions imposed by start-up or shut-down of a long line in mid-winter conditions (-60°F ambient temperature) could be handled most readily by an electrical heat-tracing system that distributes heat uniformly along the length of the pipeline. The Applicants would therefore propose to install such a system on the gathering lines linking the Niglintgak cluster to the Taglu gas plant, and those linking the Parsons Lake C and E clusters to the Parsons Lake gas plant. The shorter gathering lines linking the Taglu and Parsons Lake producing clusters to the respective gas plants could be operated without a heat-tracing system.

The Applicants would provide methanol-injection facilities at each producing cluster to prevent hydrate formation before entry into the

gathering system during start-up. These facilities would provide a back-up to the primary hydrate-control system.

The Applicants would also provide methanol-injection facilities at major low spots on the longer gathering lines, to prevent formation of gas-hydrate or ice plugs that might result from a cold-weather shut-down.

4. Stress Analysis - Above-Ground Piping

a) Design Considerations

The gathering systems proposed by the Applicants have been analyzed to select optimum line configurations. A first step in conducting the stress analyses required was determining the type and magnitude of the loads imposed on the pipeline. Forces considered in the analyses included thermal expansion, pipe weight, static snow and ice loads, static and dynamic wind loads, and seismic loads imposed by earthquakes.

Maximum allowable stresses have been determined in accordance with CSA Standard Z184-1973, "Gas Transmission and Distribution Piping Systems." The assumption has been made that the pipe used in constructing the systems would be 70,000 PSI yield-strength material CSA Grade 70.

b) Pipeline Configurations

The pipeline stress analyses the Applicants have so far carried out could only be preliminary, as the precise locations of several clusters would have to be determined, and no detailed field surveys of the proposed pipeline routes have been made as yet. However, the lengths of various segments and the terrain over which they would have to pass indicate

to some extent the gathering-system configurations that would be used. The individual gathering systems are shown schematically in Figures 8 and 9, and are characterized by the following:

- In the Taglu field, individual flowlines would be run from each well to the gas-plant location over a level land surface, as outlined in Section III.

- In the Parsons Lake field, separate group and test lines would link the Parsons Lake D cluster to the Parsons Lake plant. The longer lines from the Parsons Lake C and E clusters would pass through a rolling terrain dotted with small lakes. It is anticipated that, to a large extent, the final configuration of these lines would be dictated by the topography. Although no detailed analysis of the lines has been carried out, it is anticipated that the basic configurations discussed below for the Niglintgak line would be used wherever long, straight runs were practicable. No special problems are foreseen in the detailed design of the Parsons Lake C and E gathering lines. Each would be individually designed to take into account special topographic features. Where possible, permanent roads would be built adjacent to the pipeline right-of-way to provide ready access for inspection.

The Niglintgak-Taglu line would be some ten miles long and would cross terrain that is generally low with little vertical relief. Five stream crossings would be needed and several lakes would have to be bypassed. In general, however, it appears that the line could be constructed by linking several straight segments each 1-2 miles long. These straight segments of line were analyzed in some detail to determine the effects of various expansion-loop and support configurations. Several

configurations would provide satisfactory systems, and the one finally selected would be that which proved most economical to construct and required the narrowest right-of-way. Figure 10 shows a preliminary design configuration.

c) Pipeline-Support Configurations

The basic pipeline configuration developed as a result of the stress analyses would provide the following features:

- Anchor supports preventing both lateral and longitudinal pipe movement.

- Expansion provisions midway between anchor supports to provide the necessary freedom of movement to accommodate thermal expansions without overstressing the line segments.

- Rigid supports between anchor points, spaced as required to limit pipe stresses.

These features are treated in additional detail below.

d) Support Types

The stress analyses have indicated that three types of support would be needed to anchor the above-ground pipelines adequately against external and operating loads, and provide the freedom of movement necessitated by thermal expansion and contraction of the gathering lines. A schematic representation of the support types and locations is shown on the aforementioned Figure 10.

The first type required is an anchor support, which prevents pipe movement of any kind. Anchor supports would be spaced and located to:

- Limit pipe motions, anchor loadings and thermal stresses.
- Resist external thermal, wind and seismic loadings, and isolate any induced vibrations.

- Resist normal or transient operating loads applied to the pipeline.

For individual lines the spacing between anchor supports would depend mainly on the line size. It is anticipated that 2500 feet and 2000 feet between line anchors would be the practical maximum spacings on the 20-inch diameter Niglintgak-Taglu line and the 16-inch Parsons Lake lines respectively.

The second support type would be a guided rigid support designed to restrict lateral pipe motions. These supports would be required to curb vibration tendencies and help resist lateral wind and seismic loads. Guided supports would be more or less equally spaced, and would make up about one-third of the total number of supports between anchor points. Maximum spacing between guided supports would be approximately 150 feet for the 20-inch Niglintgak-Taglu line, 120 feet for the 16-inch Parsons Lake lines, and proportionately less for the smaller Taglu and Parsons Lake lines.

The third, and most numerous, support type would be a rigid support that would provide complete freedom for lateral and longitudinal movements of the pipeline. The spacing of these supports would be dictated largely by the following needs:

- To limit the effect of a resonate wind condition on the pipe, especially the bending stresses due to vibration.
- To limit the longitudinal bending stresses due to weight.

- To limit the mid-span sag.

- To keep the span as large as possible, in order to reduce the number of supports required and, hence, support costs and environmental disturbance.

It is anticipated that two rigid supports would be required midway between each two guided rigid supports.

5. Gathering-Line and Support Systems

Above-grade pipelines would be supported on structures consisting of timber piles frozen into the permafrost and topped with steel super-structures. As discussed in Section 4, three types of structure would be installed: anchors that permit no line movement, lateral-restraint supports that allow the pipeline to move in a longitudinal direction only, and supports providing no restraint either lateral or longitudinal. Wherever movement was required, it would be provided for by low-friction Spencer sliding bearings. Forces would be transmitted between the carrier pipe and the supports through the insulation and jacketing at all supports. At anchors the forces would be transmitted through full-encirclement sleeves welded to the carrier pipe.

The pipeline supports would resist the loads caused by the weight of the pipe(s) and insulation, the weight of the gas and condensate, the weight of water used for hydrostatic testing, and the weight of all ice and snow that might accumulate on the pipe and supports. They would also resist the loads caused by wind, seismic action, thermal expansion and contraction of the carrier pipe(s), and friction forces of product moving in the line.

The support system would provide for a minimum of four feet clearance from the bottom of the carrier pipe to grade. This clearance would allow free passage of small animals, and prevent wind-scouring of the tundra below the pipe. In areas subject to flooding, the support system would maintain the carrier pipe above maximum flood level.

Supports carrying single lines set at four feet above grade would require two piles per support. Supports carrying multiple lines, or lines set at more than four feet above grade, might need additional piles. Piles would be set into the soil to a depth of up to 20 feet below grade. Holes would be bored into the soil and the piles frozen in with a soil-slurry backfill. For all supports near river channels, ice protection around the support structures would be provided.

6. Gathering-System Stream Crossings

The Applicants envisage that both above-grade and buried stream crossings would be used in constructing the proposed gas-gathering systems. The type chosen would be dictated primarily by the width of the channel and its classification as a navigable or non-navigable waterway. Generally, it is anticipated that buried crossings would be the more economical and practical type for navigable streams, as the minimum clearance requirements would make suspended crossings extremely costly and difficult to construct. Other factors that would be assessed in selecting a stream-crossing method include:

- The probability of bottom-scouring at the crossing location.
- The stability of the river channel and embankment.
- The risk of ice jams.

A discussion of proposed buried and above-grade crossing techniques is presented in the following sections.

a) Buried River Crossings

Buried crossings would be proposed for three channels crossed by the Niglintgak-Taglu line. In general, small channels of 300 feet or less can be economically spanned with an overhead pipe-arch bridge. The buried crossings that would be installed would be of conventional design, but with certain provisions for maintaining the permafrost while transporting heated product.

All buried river crossings would be constructed at locations where the banks are stable and channel meander is least likely. They would be buried at a minimum of four feet below the maximum scour depth determined by channel surveys.

The buried crossing pipe would be covered by polyurethane foam insulation, a polyethylene jacketing material, and concrete.

The polyurethane foam insulation and the polyethylene jacket would be factory-applied. Varying insulation thicknesses would be used across the length of the crossing. The insulation would keep the internal temperature of the pipe high enough to prevent hydrates from forming and sufficiently retard heat released from the line that, with the aid of mechanical refrigeration units, the permafrost zone would be kept intact.

The concrete weighting material would be applied at the construction site. The thicknesses of concrete selected would provide for 1.25 negative buoyancy under the river channel proper, and 1.00 buoyancy at all other buried locations.

Mechanical refrigeration units would be provided where needed, to keep the soil near the heated line in a frozen state. Cooling coils would be buried below the carrier pipe, from the channel edge to the

transition point where the carrier pipe rises above grade. Refrigeration units would be needed on both sides of larger crossings, but at crossings of smaller channels a single unit would suffice. Temperature monitors would be installed near the carrier pipe at several points on each crossing, to permit monitoring of the operation of the system, and to minimize the periods that the refrigeration units would have to operate.

b) Above-Grade River Crossings

Small streams and channels in the Mackenzie River Delta could be economically crossed by above-water structures. Three alternative designs were considered:

- A suspension-bridge design, suitable for crossings as wide as 1300 feet.
- A twin pipe-arch bridge design, suitable for crossings up to 300 feet wide.
- A sag crossing design, suitable for crossings up to 100 feet wide.

The Applicants would use the latter two types of overhead structure in the proposed gathering systems. The suspension-bridge design has been excluded in favour of buried crossings, because of the size and complexity of structure that would be needed to provide navigational clearance for water-surface traffic.

All river crossings would be built at locations where banks are stable and channel meander is least likely.

Sag crossings would be installed over all water crossings less than 100 feet. The carrier pipe would be an extension of the pipeline to the water-crossing edge, being of the same material and size and encased in the same insulation and jacketing. The crossing would be founded on anchors

located on each channel bank. The anchors would be timber piles embedded in the permafrost. Guy wires would attach them to the midpoint of the carrier pipe, to ensure stability under the action of wind forces.

Twin pipe-arch crossings would be installed over all channels more than 100 feet and less than 300 feet wide. Each pipe of the twin arch would be of the same nominal diameter, wall thickness, and steel grade as the pipeline to the crossing edge. Cross-bracing between the arches would be welded pipe and fittings suitable for low-temperature service. The entire structure would be insulated and encased in jacketing. Only one pipe would be utilized to transport product; the other would provide structural integrity and be available as standby. The entire structure would be founded on anchors consisting of piles embedded in the permafrost and capped with concrete.

The arch would be pre-formed in sections by cold-bending line pipe. Each section would be hydrostatically tested after bending, before being sent to the construction site.

A gravel pier would be built for ice protection around each crossing-anchor installation. The piers would be higher than the maximum flood and the gravel surfaces would be protected by concrete slabs.

Construction of all above-grade river crossings would be completed in winter, when construction machinery can traverse the channel ice. Final hydrostatic testing of the crossings would be part of the main line test.

7. Gathering System Safety Features

The Applicants would install devices to control or monitor the pipeline operation, thus protecting the line against overstressing and ensuring that a system malfunction would cause no major damage. Safety features would:

- Protect the line against overpressuring.
- Protect the line against overheating, in order to limit thermally induced stresses, prevent excessive expansion, and preserve the insulation.
- Detect pipeline leaks.
- Detect fire and explosive gas-air mixtures within block-valve or refrigeration modules.
- Provide block-valve and blowdown facilities, so that line segments could be isolated and de-pressurized.

8. Corrosion Control

The produced fluids transported by the proposed gathering system would very likely be corrosive. If required, an inhibitor would be injected at the well clusters to protect the line against internal corrosion.

At various points along each line access would be provided to the bare pipe for ultrasonic and X-ray monitoring of the wall thickness. Line-access fittings would also be provided at several points to allow insertion and removal of corrosion probes and coupons. Internal-inspection pigs would be run at regular intervals to detect corrosion pitting and/or any reduction in thickness of the pipe wall. The liquids separated at the plant inlet would be analyzed regularly to determine changes in iron concentration.

The line insulation would have a galvanized outer jacket to control external corrosion. The buried river crossings would be protected by a suitable impressed-current cathodic-protection system.

Insulating flanges would be fitted at the ends of each line, to isolate the gathering lines from well clusters and gas-plant sites.

C. MATERIAL SPECIFICATIONS

1. Linepipe

Gas-gathering systems in the Mackenzie Delta would need three kinds of linepipe to serve in the following capacities:

- a) Above-ground straight-pipe sections.
- b) Above-ground expansion-loop sections.
- c) Buried sections (e.g., major river crossings).

The first two functions require steel pipe suitable for ambient temperatures as low as -60°F. The third imposes much less severe service conditions (minimum operating temperatures in the range of 15-20°F). At present, the Applicants would propose the following grades of steel linepipe:

a) CSA Grade 70 Category III linepipe for the straight-run above-ground sections. It is anticipated that requirements for diameter sizes could be met by pipe manufactured by a seamless process, and that 20"-24" diameter sizes would be manufactured by a double submerged-arc spiral-weld process. Grade 70 material would also be used for long-radius (40 or more diameters) bends in the system.

b) CSA Grade 52 linepipe for the above-ground expansion-loop bends, where a nominal bend radius of 10 diameters would be maintained.

c) API 5L Grade B linepipe for buried pipe sections.

The Applicants would plan to use the high-strength X-70 pipe in the above applications primarily to reduce the weight of pipe sections per foot and thus keep down the size of construction equipment needed in the field. They recognize that should X-70 pipe be unavailable in the quantities and wide variety of sizes required for the gathering

system, lower-strength grades would have to be used in some or all of the systems. Such a change in specification would not adversely affect the proposed designs or installation techniques.

The Applicants recognize the wide spectrum of service conditions to which the exposed above-ground piping in the Mackenzie Delta gas-gathering system would be subjected. They would apply stringent metallurgical specifications to all pipe orders, and carry out adequate inspection in the pipe mill to ensure that the product conformed to specification. Pipe specifications would ensure that the physical, chemical, metallurgical and mechanical properties of all pipe ordered met the mandatory requirements of the latest editions of the following standards:

CSA Standard Z184, "Gas Transmission and Distribution Piping Systems"

CSA Standard Z245.1, "General Requirements for Plain-End Welded and Seamless Steel Linepipe"

CSA Standard Z245.2, August Draft 1973, "Large Diameter High Strength Steel Linepipe"

CSA Standard Z184 - December 1973, "Additional Minimum Requirements of Gas Pipelines In Northern Regions"

The specifications would be written to ensure that product properties considered especially important in the intended service are adequately defined as follows:

- a) Acceptable resistance to brittle fracture would be specified in terms of transition temperature.
- b) Acceptable shear-fracture arrest properties would be specified in terms of Charpy V - notch shelf-energy levels.

c) An effort would be made to limit pipe susceptibility to cracking by means of the following measures:

- detailed specification of the steelmaking practice
- detailed nondestructive testing requirements
- high-pressure proof-testing of each pipe joint, in

the mill

2. Pipe Insulation and Jacketing

a) Insulation

Thermal insulation of the gas-gathering lines would consist of rigid urethane foam. To meet the necessary insulating and strength requirements for the intended service, the urethane foam would have the following properties over the full range of operating temperatures (-60°F to 150°F):

- minimum compressive strength of 20 psi.
- thermal conductivity of 0.13 BTU/ft.²°F. Hr/In

Urethane foam has been used successfully in many major transmission lines. The Applicants would choose it for the Mackenzie Delta because it has the following desirable properties:

- low thermal conductivity
- low water absorptivity
- high resistance to mechanical damage (when adequately jacketed)
- high resistance to hydrocarbon attack
- low cost as compared with other suitable insulations

The urethane insulation would be applied to straight-pipe joints under shop conditions by a foamed-in-place process wherein a continuous

spiral-seam protective jacket is formed around the pipe wall, and urethane foam constituents are injected into the annular space between wall and jacket. In this process, foaming action continues after injection, thereby assuring reasonably uniform insulation around irregular surfaces such as the heat-tracing system that may be affixed to the pipe wall. The cured urethane foam forms a strong bond to both pipe wall and external jacket. The fabrication process would be adequately inspected, to ensure that the finished product had the properties noted above.

Pipe joints would be insulated in the field, after welding, with pre-formed rigid urethane blocks. Pipe bends would have similar insulation, applied wherever possible under controlled conditions in fabrication-site work enclosures, to assure a satisfactory product. Other irregular surfaces would be insulated with either pre-formed urethane blocks or spray-on urethane foam as the type of surface required.

b) Jacketing

A galvanized-steel or equivalent jacket would be bonded to the outside surface of the insulation to protect the urethane from water, weathering (with risk of gradual decay in thermal insulating properties) and mechanical damage.

The Applicants would choose jacketing of the spiral-seam type so it would be compatible with the proposed foamed-in-place urethane insulating process. The spiral jacket seams would be of the locking type for protection against water. At joints, and over irregular surfaces where the spiral locking seam could not be used, jacket seams would be sealed with a mastic compound.

D. CONSTRUCTION

1. Construction Schedule

a) General Description

Construction of the gas-gathering system the Applicants propose would include such diverse activities as preconstruction surveys, mobilization of personnel and equipment, actual field construction, hydrostatic pressure testing and commissioning. Measures would be taken throughout to ensure maximum protection of the environment. Where possible, the components of the gas-gathering system would be of modular design, to minimize the amount of work to be done in the arctic.

b) Preconstruction Activities

Completing the final design of the gathering systems in the Mackenzie Delta might require the following preconstruction surveys:

- soil sampling and analysis
- final right-of-way selection
- selection of river and stream crossing points
- additional monitoring of ice movement
- determination of maximum water levels

The preconstruction activities would probably be supported from established camp facilities the Applicants now operate to support seismic and exploration drilling. Activities would take place in both summer and winter, with transportation being by helicopter, boat, low-pressured tracked vehicle, and float- and ski-equipped aircraft.

c) Construction Activities

The gathering systems would be constructed mainly during the winter months, from snow roads prepared by the Applicants in the manner

described in Section 2.a to minimize terrain damage. Primary activities would include:

- construction of pipeline supports
- assembly and welding of above-ground pipeline
- construction of stream crossings
- installation of prefabricated modules housing block valves, blowdown equipment, and refrigeration
- hydrostatic testing of the completed line
- installation of power-distribution and communication facilities
- installation of animal crossings

A typical sequence of operations for the Parsons Lake system is shown in Figure 11.

d) Manpower Requirements

Estimated manpower requirements for gathering-system construction are summarized in Table II.

Construction personnel would be based at temporary camps at Parsons Lake and Taglu plant sites.

2. Construction Techniques

a) Winter Roads

The Applicants would expect to conduct all construction activities from winter roads prepared along the pipeline right-of-way. In Parsons Lake, the permanent roads discussed in Section VI might also be utilized for some of the construction work across the frozen tundra. Travel by conventional wheeled vehicle would not start until adequate roads have been established.

Winter road surfaces would be prepared wherever possible by blading and compacting snow. Maximum use would be made of frozen river channels and lake surfaces.

b) Pipeline Supports

Construction of gathering-line supports would entail installing piled foundations of wooden or steel pipe, then fitting pipeline support frames. Piles would be placed in drilled holes, backfilled with a soil/water slurry, and allowed to freeze back before support frames were installed. Conceptual pipeline supports are illustrated in Figures 12 and 13.

c) Buried River-Crossings

The buried river-crossings would be built during the winter construction period, from the channel ice surface. Pipe joints would arrive at the crossing sites with insulation and jacketing installed, and the necessary bends completely formed. A heated temporary structure would be used during welding and installation of the concrete weighting material. The channel banks would be trenched, and the tundra surface carefully replaced after the crossing was completed.

The pipeline trench would be deep enough to avoid riverbed scouring. Where feasible, pipe entry and exit would be in permafrost-free soil along the river banks. Where such was not feasible, refrigeration coils would be placed in the trench if necessary. The entire assembled crossing would be lowered into position by machinery operating from the ice surface and the channel banks. Backfilling of the banks would be completed with dry, tamped material and water barriers of clay or bentonite. The channel bed would be filled by normal silting action. The banks would be re-vegetated during the following summer.

Figure 14 illustrates a conceptual buried river-crossing. Secondary crossings would be installed in the same way.

d) Above-Ground River Crossings

Above-ground river crossings would be erected during the winter construction period. The anchor piles and anchors would be placed and allowed to stabilize before building the type of crossing shown in Figure 15. The arch pipes would be pre-bent to the correct radius, and would arrive at the site with electric heat-tracing, insulation and jacketing installed. The individual arches of the twin-arch structure would be assembled on skids and raised into final position. Bracing between the arches would be welded after erection.

e) Refrigeration, Blowdown and Block-Valve Modules

Refrigeration units (where needed), blowdown facilities, and block valves would arrive at the construction site as complete steel-housed modules. All modules would be tested at the assembly plant before being shipped to the Mackenzie Delta. The support piles for the refrigeration modules would be placed in bored holes, and gravel pads formed around the piles before the modules were set. The refrigeration coils placed when the buried river-crossings were built would be extended through the gravel pads and tied into the modules to complete this phase of construction. Figure 16 shows a typical refrigeration module.

Blowdown modules containing block valves in addition to the line blowdown facilities would be installed in the same way as the refrigeration modules.

f) Pipeline Assembly and Erection

Pipe intended for service in the straight sections of the above-ground system would be shipped to the Mackenzie Delta with electric

heat-tracing sections, insulation and jacketing completely installed. Pipe intended for use in expansion-loop sections would be shipped bare, and the loops would be fabricated and fitted with electric heat-tracing piping, pre-formed insulation, and jacketing in large, temporary, heated buildings next to the camp facilities.

Individual pipe joints would be welded into segments two or three joints long before being transported to the erection site. Line segments would be positioned on the support structures before being welded. Welding, X-ray inspection, and installation of electric heat-tracing connectors and pre-formed insulation and jacketing would be completed in portable heated enclosures. Each line segment would be positioned on its supports in a manner that provided the correct pre-stress for the ambient temperatures at the time the tie-in welds would be completed. Low-friction bearings would be centred on each support, and vertical adjustments made to level the line.

g) Hydrostatic Testing

Hydrostatic pipeline testing in the Mackenzie Delta area would be much like hydrostatic testing in other areas of Canada. The tests would be carried out during the latter part of the winter construction season. Water would be the test medium in all cases. Sizing scrapers would be passed through the lines by pressurized air before the test water was introduced. Electric heat-tracing would be energized before introduction of the test water and throughout the test.

All pipelines would be tested to 90 per cent of their specified minimum yield stress on the basis of hoop stress for 24 hours. In addition, certain critical sections would be tested further before the final test, as follows:

- Buried river crossings - each joint would be tested at the pipe mill, and the assembled crossing would be tested for four hours before being lowered into the ditch.

- Above-grade river crossings - each assembled section would be tested for four hours before being shipped to the Mackenzie Delta area.

- Animal crossings - each assembled carrier pipe would be given a four-hour test before being pulled into the casing pipe.

Charts of pressure versus time and temperature versus time would be obtained for all tests.

The pipelines would be dewatered with suitable scrapers pushed by pressurized air. Water free of additives could be routed into any watercourse after the test; water with additives would be routed to a disposal well.

h) Power Distribution and Communication Facilities

As now envisaged, to distribute electrical power from central plant locations to remote clusters, primary substations, pole lines and service points would have to be built concurrently with the gathering systems. The Applicants would also duly consider generating electricity at each remote cluster.

Poles for the power lines would be erected while the pipeline supports were being installed. Stringing crews would then assemble the pole line hardware, the power lines and the communication cables linking remote stations to plant control centres. Temporary engine-driven generators would be used for electrical power during the construction phase.

The communications cables would be terminated at various strategic locations throughout the gathering system, to provide voice link-up to plant control centres.

3. Equipment Requirements and Temporary Buildings

The types and quantities of equipment required for the gathering system were estimated on the following bases:

- the need to meet a 1979 start-up date
- efficiency factors reflecting the severe operating conditions

in the arctic

- transportation constraints

- a summary of estimated typical major equipment requirements for the Parsons Lake or Niglintgak-Taglu gathering systems, as provided in Table III.

4. Transportation

Construction equipment, supplies, repair material and personnel for the gathering system would be brought in to the work area in the same way as described in Section III for cluster producing facilities.

On-site gathering-system transportation would take place in winter, when conventional equipment can use winter and permanent roads.

5. Handling of Materials

Wherever possible, materials for the gathering system would be assembled in southern locations to minimize on-site construction. Pre-fabricated materials would include:

- insulated and wrapped line pipe
- modular refrigeration, blowdown and block-valve facilities
- partially assembled pipeline support structures
- warehouses and construction shops

Winter roads would allow materials for the gathering systems to

be transported from the staging areas to the pipeline right-of-way by conventional vehicles. Portable cranes would be provided on site as required.

E. OPERATIONS AND MAINTENANCE

1. Operations

a) Gathering-System Operations Characteristics

The gas-gathering lines envisaged by the Applicants for use in the Mackenzie Delta would transport all well effluent (gas, water and hydrocarbon liquids), and would be elevated throughout their length except where they had to be buried to cross navigable streams. The primary problems in operating such lines arise in the cold winter months, when it is necessary to

- start up a cold, pressurized or depressurized line segment
- shut down and depressurize a line segment
- reduce flow rate through a line segment

The Applicants anticipate that gathering lines could be insulated well enough to allow hydrate-free operation at normal flowing conditions during extreme cold weather. The critical operations noted above, however, call for additional hydrate-control measures. As expressed earlier in Section B, the Applicants would propose to use an electrical skin effect heat-trace system for this additional control. The heat-trace system would be activated before any critical operation, to ensure that line temperatures were kept above the gas-hydrate formation temperature. An added advantage of the heat-trace system over other control methods is that cold lines can be warmed up before being pressurized, or kept warm when flow is halted, thus removing any need to fully stress a cold pipeline.

Methanol-injection facilities would be provided for other purposes at each well cluster, and could be used to control hydrates in the gathering lines should the heat-trace system fail. Methanol-injection

facilities would also be provided at low spots on the longer gathering lines, so that liquid slugs could be adequately inhibited during an extended shut-down.

Generally it would be desirable to maintain stable flowing conditions in the longer gathering lines during cold weather. Wherever possible, fluctuations in gas plant throughout would be made up from the well clusters near the plants, thus simplifying hydrate control.

b) Normal Operating and Protective Instrumentation

Gathering lines would be operated from an operations centre at the gas-processing plant. A computer-based supervisory control system would provide the main operational control. Electrical signals from instrumentation located on the gathering lines would be displayed locally and transmitted to the gas plant through a supervisory system linking the plant to all remote producing facilities, where the data would be monitored and corrective measures or alarms initiated if necessary. Operations personnel would not be required to man any of the remote gathering-line locations during normal operation, but an operator would have to visit the remote location and manually reset the system if the control system triggered an emergency shut-down. The Applicants would thus ensure adequate inspection before the system was restarted.

Protective and operations instrumentation would include devices to monitor and/or control certain parameters for any given gathering line as follows:

- Monitor pipeline operating pressures and temperatures.
- Protect against overpressuring of the gathering lines.
- Determine excessive pressure drops (indicating a line leak or break).

- Protect against low or high pipeline temperatures.
- Measure ground temperatures at underwater crossings and similar zones of concern.
- Monitor the electrical power systems.
- Monitor the status and operation of the hydrate control.
- Indicate the launching or receiving of a pig.
- Monitor operation of refrigerating units at buried stream crossings.
- Monitor and control line block valves.

2. Routine Maintenance and Surveillance

Surveillance of gas-gathering systems in the Mackenzie Delta would take the following forms:

- Visual inspection by maintenance and operations personnel.
- Continuous monitoring of selected parameters as described in 1.b above.
- Periodic monitoring by mechanical, chemical or electronic inspection techniques, or nondestructive tests of such parameters as corrosion rates.

The Applicants would propose to carry out a weekly visual surveillance of each gathering line and its associated facilities. Surveillance on the Taglu and Parsons Lake gathering systems would be largely from wheeled vehicles operating on the all-weather roads proposed for the area. Surveillance on the Niglintgak-Taglu line would be by helicopter in summer and a combination of helicopter and tracked vehicle (operating on prepared winter roads) for the rest of the year. The visual surveillance would consist mainly of:

- checks of pipeline and associated facilities for leaks
- checks for damage to pipe insulation and jacketing
- checks for abnormal pipe movements
- inspection of pipeline supports and bearing pads
- checks for disturbance of the ground surface, to prevent permafrost degradation.

Routine maintenance on all equipment would be carried out as recommended by the manufacturers. Access for maintenance personnel would be by the transportation media already described. Adequate spare-parts inventories would be stocked at well clusters and/or gas plants, to ensure continuity of operation. Routine maintenance would include regular checks of operations and protective instrumentation, electrical systems, flood-control devices, refrigerating systems, cathodic-protection systems, and relief valves, and minor adjustments to pipe supports.

3. Nonroutine Maintenance and Repairs

Nonroutine maintenance and/or system repairs would be carried out as needed. The Applicants would stockpile enough pipe, gravel, piling, structural steel and other major construction materials at plant-cluster or river-crossing locations to prevent lengthy shut-downs of a producing system during nonroutine repair or maintenance work.

The main problem in carrying out nonroutine maintenance in summer is access to the work site for potentially heavy materials and construction equipment. Large helicopters would probably be needed to place protective matting or pads, and to transport equipment and materials to the site.

V. AIRSTRIPS AND HELIPORTS

A. GENERAL DESCRIPTION

1. Air Transportation

The use of aircraft is fundamental to the initial construction phase, routine operations and subsequent maintenance of production facilities. With the lack of highway access in the Mackenzie Delta, air transport is the only means of providing regular service to the many sites during the non-winter months. Aircraft would be used to transport men and perishable goods, and for unscheduled equipment deliveries into the Delta, as well as to move maintenance and operations personnel within the work zones of each Applicant's productive area.

The Applicants would use both fixed-wing aircraft and helicopters for the construction, operation and maintenance of the facilities. Each gas plant would have an airstrip on the site, to be accessible by fixed-wing aircraft. Remote facilities such as production well-clusters, river-crossing facilities, valve stations, etc., where helicopter service is required, would have heliports.

Under consideration is the use of air-cushion vehicles (hovercraft) for moving personnel and light freight in servicing the plant and remote sites. This mode of transportation is most suited to the river-channel areas of the lower Delta, and will probably be used most in the area of the Taglu Plant.

2. Location of Landing Facilities

Permanent locations for facilities to service the proposed production equipment would be chosen after detailed climatic and field investigations. Wherever possible the locations would be chosen to avoid

areas of high ice content, avoid interruption of normal drainage patterns, and reduce the amount of fill material required. The general landing areas are shown in Figure 17.

3. Type of Landing Facilities

To support the Taglu gas plant in the lower Delta, a gravel-surfaced landing strip for fixed-wing aircraft would be built on the low land beside the plant site. STOL-type aircraft would operate regularly to and from this airstrip. The Applicants would not propose to have permanent aircraft-servicing facilities (hangars, fueling) at this strip, but would hope to use the installations at other airstrips already in the Delta, provided they were compatible with its needs.

Near the Parsons Lake gas plant, on the higher land away from the river channels, a larger airfield would be prepared to accommodate large passenger and freight aircraft such as the Boeing 737, Lockheed Electra or Lockheed Hercules. This large installation would be self-sufficient in terms of fueling facilities, servicing, etc. Besides serving the gas plant, this large airstrip would take care of the Applicants' exploration needs in the Mackenzie Delta areas.

Each airstrip would have offstrip parking, to keep the landing surface clear as is required for safety. At Taglu this parking area would accommodate a number of STOL-type aircraft at once to handle the initial heavy movement of manpower.

Where production sites were not normally manned, or roads were either lacking or unusable, transportation would be by helicopter. All sites would have well-marked pads for these vehicles.

Main plant sites would be provided with shelter beside the airstrip for the use of personnel in an emergency.

Each air-transport facility would have access to the servicing site by a roadway or gravel corridor along which freight and supplies could be moved when unloaded.

4. Traffic Frequency

Use of the air-transport facilities would vary in intensity as the associated projects were phased into existence. During preliminary investigations and in the construction phase, the area would see sporadic heavy air traffic. Once the plants were operating and a well-scheduled movement plan had been introduced, flights would be on a reasonably regular schedule. The large airstrip, which would also be used to support exploration, would of course have to provide unscheduled service from time to time because of the seasonal nature of these activities.

It is proposed that construction of both airfields and helicopter pads in the Delta begin early in the construction schedule, so that maximum use could be made of these facilities during the periods of heavy and concentrated activity.

At this time it is difficult to provide clear estimates of use frequency and types of aircraft that would be utilizing the facilities, because construction and contracting methods have not been established. Basic manpower movement in and out of the two main Delta sites during peak construction would require multiple flights daily. Destinations and departures of these flights would vary, but most would be from the Inuvik airport. Long-distance flights terminating or originating at the Taglu plant strip would probably be few. The large aircraft facilities

proposed for the Parsons Lake plant, however, would provide for direct service flights between the Applicants' Delta operations and Canadian cities to the south. Multiple weekly flights of large passenger and freight aircraft would be envisaged from this airstrip.

Intersite flights between airfields in the Delta would be routine during the construction phase. Helicopters would be used intermittently for transport, to allow subprojects not accessible by either roads or airstrips to be effectively administered during construction.

Once the plants were satisfactorily in service, the use of aircraft would decrease. Rotation of operating personnel and resupply of perishable goods would require multiple flights weekly with fixed-wing aircraft. Plant sites not accessible by road would need helicopters to handle maintenance and servicing. Depending on the activity of other operations in the Delta, these machines might or might not be based at the plant sites.

B. DESIGN

1. General

The design work done to date and described herein applies to the construction of two permanent airstrips for winged aircraft, and a number of helicopter landing pads. In developing these designs, geotechnical data were used as described in Section II. Figure 18 represents conceptual cross sections of the two proposed airstrips. Final designs would be completed after detailed field investigations.

2. Embankment Design

The design of airfield embankments in the Mackenzie Delta is similar to that of roadway embankments.

Surficial geology and land forms in the Richards Island and Parsons Lake areas differ significantly. The very low-lying river-delta deposits at Richards Island, in contrast to the rolling terrain and granular deposits at Parsons Lake, influence the height of embankment that must be built at the different sites. The design and construction methods used to achieve stability would be the same at both sites because of the continuous permafrost. Embankment heights above the tundra surface in both areas would be designed to maintain the 32° F isotherm line within the fill materials. This design would protect the permafrost and at the same time provide the structural strength necessary for the imposed aircraft loadings.

At Richards Island the landing area would lie entirely within recent river-delta deposits of fine silt, silty sand, organic silt, peat and possible minor traces of gravel. Most of the area is subject to flooding during river breakup, as well as during wind-initiated summer ocean storm-tides.

The finished surface elevations of the strip would be built to a height above the best determination of the maximum high-water level in past years.

The Parsons Lake landing areas are characterized by glaciofluvial surficial deposits intermixed with lacustrine sediments. The entire area is high and not subject to flooding, and the height of embankment would be governed by the stability requirements of the permafrost.

In all areas, culverts would be placed to prevent water from being entrapped and ponded by the structure.

3. Dimensions

The table below indicates the approximate major dimensions of airstrips and helicopter pads to be constructed.

	<u>Length</u> <u>(ft)</u>	<u>Width</u> <u>(ft)</u>	<u>Travelled Area</u> <u>(ft)</u>
Airstrip			
Parsons Lake	6500	390	6500 x 150
Richards Island	2500	200	2500 x 100
Helicopter Pads	60	60	60 x 60

C. CONSTRUCTION

1. Construction Methods

The construction of suitable embankment structures on the tundra surface to form aircraft runways, roads, and service pads would call for special procedures unique to arctic areas. Construction methods in both the Taglu and Parsons Lake areas would be roughly the same, in that elevated granular embankments would be laid down without disturbing the existing ground surfaces.

In the lower flat areas of the Delta the surface elevations of the runways and landing strips would be built up high enough to remain above flood level. They would therefore be constructed as high, insulated fills. The granular materials needed would be obtained from pits already identified in the Ya Ya Lake area on Richards Island.

In the upland area of Parsons Lake the embankments would also be built of gravel and sand, but here the height would vary to accommodate the rolling terrain. Material for constructing the Parsons Lake airfield would probably come from source pits to be developed in the area. Maximum use would be made of these local gravel deposits to provide the necessary assortment of granular material.

Construction of the airstrip and roadway embankments would involve activity at the material source pits, in intersite transportation and at the chosen locations.

The development of adequate quantities of suitable local mineral material is discussed in Section VIII under Resource Commitment. During summer months the gravels, which constitute part of the permafrost zone, would be excavated as the surface layers thawed and stockpiled nearby.

Enough would be assembled in this way to provide for the construction needs of the following year.

Fill material for the airstrip and heliport embankments would normally be placed during the winter construction season, when trucks can traverse the Mackenzie Delta area on winter haul roads. When feasible, and necessary, summer barging would be used to extend the construction season.

The previously dried and classified material would be spread on the fills in a series of shallow lifts. Initial conditioning would be with compactor dozers. Culverts would not be installed in winter. Airstrips would be ditched at watercourses before spring runoff, and the culverts installed during the summer.

Insulation would be placed manually on a level layer of fine fill material. Another layer of fine fill material would be pushed over the insulation by a light dozer before heavy vehicles placed the top lift of the grade.

During the summer following initial embankment construction, further conditioning with graders and vibratory compactors would be needed. Stockpiles of fill material would be maintained near the work areas to provide the fill to compensate for embankment settlement.

Embedded electrical facilities for runway lighting, communication facilities and navigation aid would be installed during the summer.

Paving when specified would be placed during the summer by normal paving techniques.

2. Manpower

Total manpower requirements for the two airstrips is estimated to be about 300,000 man hours. Peak employment levels, which would occur during the winter gravel-haul season, would be in the order of 110 men.

D. MAINTENANCE

The airstrips in the Mackenzie Delta would be key facilities to the operation of the plants. For this reason, operation and maintenance of the airstrips would be administered from the control centre of each plant. It would entail operation of the communications, navigation, flight-control planning, meteorological and landing-system equipment. Building maintenance, fire protection, maintenance of the drainage systems, and snow removal would also be handled by the airstrip operator.

Embankment settlement would be the main maintenance problem and would be rectified by adding granular fill. Maintenance would start immediately after construction.

Some of the equipment needed for runway maintenance could also be used for maintaining roads.

VI. ROADS

A. GENERAL DESCRIPTION

1. Road Transportation

Roads within the Mackenzie Delta would provide access from the plant facilities to the dock, airstrip and well clusters. All roads would be designed for all-weather service.

Two classes of roadway are envisioned. The access roads to the docks would carry the heaviest loads and would therefore be wider and of higher-quality materials. These roads would have a traffic surface approximately 35 feet wide, while those to the well clusters and airstrip would be about 20 feet wide. Maximum grades and alignment deflections would be dictated by the class of vehicle using the road.

2. Location of Roadway Facilities

Permanent locations for facilities to service the proposed production equipment would be chosen after detailed field investigations. Where there was a choice of locations and alignments, roadways would be routed to avoid areas of high ice content, minimize interruptions of normal drainage patterns, and reduce the amount of fill material required. The general roadway areas are shown in Figure 19.

B. DESIGN

1. General

The design work done to date and described herein applies to the construction of roadway embankments in the Mackenzie Delta. In developing these designs geotechnical data have been used as described in Section II. Conceptual cross-sections are shown in Figure 20. Final design would be completed after detailed field investigations.

2. Embankment Design

Roadway embankments in the Mackenzie Delta would be designed in the same way as airfield embankments. For the general design considerations, the reader is referred to Section V.B.2.

Specifically, roads required for access between facilities would be constructed for all-weather service. Roads that would carry light service-vehicle traffic would have a top width of approximately 20 feet; roads for heavier traffic would have a top width of 32 feet. Roadways in areas subject to flooding would be built with embankments high enough to prevent flood waters from rising above the top of the frozen part.

Roads would be designed to prevent permafrost degradation. In most instances fill materials and insulation would be used to maintain the 32°F isotherm within the embankment. In soils not susceptible to freezing, such as along an esker, cuts could be constructed to facilitate roadway alignment and grade. The highest-quality material that was readily available would be utilized; i.e., dry, non-frost-susceptible material obtained from local source pits, as outlined in Section VIII. Slab insulation might be embedded in road embankments to keep them frozen and reduce the amount of fill material required.

Culverts would be used to prevent entrapped water from pounding against the embankments. They would be insulated below to maintain the permafrost and their ends would be sealed with clay or soil cement to prevent water migration along the outside. The culverts would be of completely welded construction so that no water could seep through the joints; they would also have thaw lines or electrical heating cables inside the pipe so they could be cleared of ice and snow.

Culverts up to 10 feet in diameter would be used. Where the volume of water required larger openings, pile-supported arches would be installed. Bailey bridges would be installed across all streams of significant size.

C. CONSTRUCTION

Roadway construction methods in the Mackenzie Delta would be the same as for airstrip construction (V.C.). The fill embankment insulation would be placed during the winter construction season and final grade conditioning and shaping completed in the following summer season. Culverts would not be installed in winter. Roads would be ditched at watercourses before spring runoff, and culverts installed during the summer construction season.

Total manpower needed for building all roads would be about 400,000 man hours. Peak employment levels, reached during the winter gravel-haul season, would be in the order of 100 men.

D. MAINTENANCE

The chief maintenance problem would be subsidence, causing undulations in the road surface. The standard procedure for removing these undulations would be to add more granular material without making cuts in the existing high spots. This maintenance would start as required after construction.

Drainage structures would have to be kept open, especially during spring breakup. Granular material for maintenance would have to be stockpiled and snow cleared from the road surface.

VII. DOCKS AND STAGING AREAS

A. GENERAL DESCRIPTION

The Applicants would consider water-borne transportation an important requirement for the construction and operation of all phases of development. To handle effectively the many types of loads, especially the very heavy equipment to be installed in the plants, suitable permanent docks would be built at widely separated locations in the Mackenzie Delta. A dock would also be needed at an important staging point in the Hay River area, for loading construction materials.

Temporary docks might be needed at the permanent unloading points, but they would be very rudimentary and would be removed as soon as they had served their purpose.

Present plans call for a minimum number of construction staging areas, and it is at these points that docks would be required. Figure 21 shows the locations of the proposed docks. They would be built to handle the mooring and unloading of river-transport barges, and in some cases of larger barges that would form part of ocean convoys brought in from the Beaufort Sea. The docks servicing the two gas plants would be the unloading points for the large modular components of the process facilities.

B. DESIGN

The docks would be built of steel sheet-piling driven into the unfrozen river or lake bottoms, with granular backfill and concrete stages. Figure 22 shows a conceptual design of the dock and staging areas.

Dock construction would be planned not to interfere with the navigation and flow of the channels of the Mackenzie River. Barges and vessels discharging or taking on loads might do so from their ends or sides.

The construction method would be to drive the sheet piling into the channel bottom, then dredge to the edge of the sheet-piling dock face on the water side. The dock facewall would be tied back to anchor piling firmly embedded in the permafrost. Gravel fill would be placed behind the piling, to raise the channel beach up to the level of the dock apron. Protective insulation would be placed where the installation encounters permafrost that might be affected by the dock configuration. Timber-pile supported concrete approach slabs would be placed over the gravel.

Laydown or storage areas for offloading material would be built beside the docks. The laydown areas would be of compacted gravel thick enough to prevent the area from being flooded during spring breakup or sea-storm tides. The storage areas in the Hay River area would adjoin the railway track.

C. CONSTRUCTION

Most of the construction would be carried out in the summer season. Barge-mounted cranes and storage would provide the facilities for driving the sheet-steel piles along the shorelines. Operating from suitable gravel pads, laid down the previous winter, holes for dock-apron paving and dockwall tie anchors would be bored and piles frozen into the permafrost.

Gravel hauled to the dock site would be placed behind the dock to form the summer staging area. Portable camps would be used for manning the various activities during both summer and winter.

Total manpower required for building the three docks would be about 300,000 man hours, with a peak demand of approximately 60 men.

VIII. RESOURCE COMMITMENT

A. GRAVEL

1. Gravel Requirements

An estimated 3,325,000 cubic yards would be required in constructing the proposed Mackenzie Delta gas plants and support facilities. The table below lists the estimated requirements by area.

RICHARDS ISLAND GRAVEL REQUIREMENTS (Cubic Yards)

Niglintgak dock and staging area	50,000 c.y.
Niglintgak well-cluster	200,000 c.y.
Niglintgak road from dock to well-cluster	100,000 c.y.
	350,000 c.y.
Taglu plant site	350,000 c.y.
Taglu well-cluster	350,000 c.y.
Taglu dock and staging area	50,000 c.y.
Taglu airstrip	125,000 c.y.
Taglu roads	50,000 c.y.
Taglu construction-camp sites (Helicopter pads, etc.)	25,000 c.y.
	950,000 c.y.
TOTAL RICHARDS ISLAND REQUIREMENTS	1,300,000 c.y.

PARSONS LAKE GRAVEL REQUIREMENTS

Plant site	240,000 c.y.
Air strip	490,000 c.y.
Dock and staging area	40,000 c.y.
Roads	800,000 c.y.
3 well clusters	430,000 c.y.
Construction camp	<u>25,000 c.y.</u>
TOTAL PARSONS LAKE REQUIREMENTS	2,025,000 c.y.

2. Gravel Sources

The raw materials needed for construction in the Mackenzie Delta would come from two main areas. The older delta sediments, which are areas of high relief along the eastern side of the Delta and Richards Island, have a number of identified mineral deposits that are workable. Most of them occur in the form of eskers, crevice fillings, kames, and kame-deltas. These deposits, some of which have been worked in the past, represent one source of material.

Another source would be in the newer delta, where outwash deltas adjacent to the older delta hills have formed in still-water bodies. These deposits have so far not been investigated thoroughly.

The main source locations for the proposed development would be the esker and kame deposits indicated in Figure 23. On Richards Island eskers are now being worked in the Ya-Ya Lake area. This deposit is accessible by barge during summer, and in winter the intricate but extensive river-channel system permits trucking without disturbance to land surfaces. The Ya-Ya Lake deposit would provide the necessary variety of material in what appears to be adequate volumes for the needs of the lower delta construction.

In the Parsons Lake area there are extensive gravel deposits that could provide the required quality and quantity of materials. They are not accessible by water, and the gravel would have to be moved overland during the winter season. The facility layout in the Parsons Lake area would be designed to allow economic road-building to spread from these deposits and, in some instances, would locate the facility beside the identified source.

3. Mining of Gravel Sources

The Applicants would open and work all gravel sources during the summer season. The gravel would be bladed off to thaw depth and pushed into windrows in the pits. When the water had drained from the windrows, the gravel would be moved to the crusher/screener and the classified materials stockpiled for winter placement. Trucking gravel would begin as soon as winter haul roads were prepared and continue through the winter to spring break-up.

The winter haul roads constructed from the gravel pits to the various construction areas would be routed on channel and lake ice as far as possible. Where there was not enough snow to build those portions of the winter haul roads that crossed the tundra, one or more of the following construction techniques might be used:

- 1) Entrapping snow behind snow-fences,
- 2) Chipping ice from lake surfaces and placing it on the winter haul roads,
- 3) Spraying water on the snow and chipped ice.

Where both gravel pit and construction site were located on or near a river channel, extensive summer barging might be used to extend the construction season.

Sources of sand and gravel would be developed as follows:

1. All clearing and stripping would be disposed of as directed by the authorizing agency. All brush and other vegetation would be disposed of by burning, or as approved by authorizing agency.
2. All sources would be so worked as to produce a final excavation that would blend as well as possible with the natural contours of the immediate area.
3. If ground water should have to be drained from the excavation, steps would be taken to prevent erosion and silting by providing flat-bottomed escape ditches, gravel ditch-lining, check dams or settlement basins as necessary. If the source were worked as a bail site, stockpiles would be so located as to allow drainage of muddy water into the pit and prevent its escape to the surrounding area. If necessary, dikes, berms, and ditches would be built for this purpose.
4. During or after completion, pit faces above the water level would be graded off to smooth, stable, gentle slopes and blanketed with the stockpiles waste material. Any material not needed to blanket the slopes would be carried beyond the edges of the pit to form a broad, low berm with gentle side slopes. Matting or other measures would be used to prevent its erosion.
5. Any source to be used as a maintenance site in future would be left in such condition that future operations would cause no serious disturbance. Enough would be kept for a working area and a waste storage; depleted portions of the pit would be restored as described under 4) above.

4. Equipment

The mining and transportation of gravel would take place over three construction seasons. It is estimated that the following equipment would be required:

a) Approximately 15 crawler-type tractor units with various attachments such as dozer blades and rippers.

10 Crawler 100 to 200 HP

5 Crawler over 200 HP

b) Approximately 80 units of gravel-moving equipment consisting of

60 Earthmovers, scrapers and haulers

20 Graders, loaders

c) Approximately 10 units of specialty items that would include

8 Compactors

2 Crushing plants

d) Approximately 15 trucks in the 3/4 to 5-ton class.

B. PILING

1. Piling Requirements

Current design criteria would call for an estimated 16,000 piles to support the structures and above-ground gathering lines planned for the Mackenzie Delta. Of this number, roughly 9000 would be needed in the Richards Island area and the remaining 7000 in the Parsons Lake area.

2. Piling Sources and Transportation

Timber piling from the Fort McPherson area appears to be suitable for construction requirements. The peeled and native spruce would be formed into pile rafts, which would be pulled down the channels to the required locations. The treated piles would be stockpiled for use as required. In the past there has not been a shortage of piling, and from all indications the Fort McPherson area appears to have adequate sources to provide the piling needed for constructing the various facilities in the delta.

Treating the piles would usually consist of hand-applying a 5 per cent solution of pentachlorophenol in heavy petroleum solvent.

IX. AUTOMATION AND COMMUNICATIONS

A. BASIC ASSUMPTIONS

1. Introduction

Although the Applicants have not developed final designs for the proposed automation and communications systems for the gas-producing operations in the Mackenzie Delta, a conceptual design study has defined the basic requirements. The conceptual design assumes that the Taglu and Parsons Lake gas plants would operate independently. Each gas plant with its associated production clusters, staff, housing and transportation facilities would be a self-contained unit. It is assumed that the automation and telecommunications needs of this unit would apply to other operating units that might develop in the region.

2. Design Assumptions

What is mainly required of the gas-production system is that it provide safe, continuous operation in a hostile but delicate environment, yet disturb that environment as little as possible. The system must therefore be highly automated and extremely reliable. Because of the locations of the plants and the distances involved, provision would be made for an extensive telecommunications facility.

To proceed with a conceptual design, certain assumptions had to be made with regard to the basic production unit, as follows:

a) Automation Facilities

All facilities would be locally controlled and designed to operate in a "fail safe" manner.

The control system would be a supervisory one, with facilities for optimization and control where economically and technically feasible.

The system would monitor:

- i) Life-support systems at the living quarters
- ii) Fire- and intruder-detection systems at all facilities
- iii) Environmental conditions

All data gathered by the supervisory system would be of a high enough quality to be used in accounting, management and regulatory reporting systems. Provision would be made for operator intervention at all levels.

Management information systems would be provided to monitor operating-efficiency and preventive-maintenance schemes, through a remote job entry tied to operations data centres.

b) Communications Facilities

The gas plant would have

i) A telephone system, for access to the clusters and the public network.

ii) A telex network for written-message traffic

iii) A facsimile transmission facility

iv) Supervisory data circuits between gas plant and clusters.

v) Computer data-access to external centres

vi) A mobile radio system, for access to people and vehicles in any part of the production unit area, and as backup for the telephone link to the clusters.

vii) An air-ground radio system for communication with aircraft

viii) Navigation aids, for safe and reliable operation of aircraft

ix) Recreation facilities, such as live television, to provide the operating staff with reasonable entertainment in their off hours.

The common carrier would provide main trunk circuits to the gas plant as well as to the plant private automatic business exchange (PABX). It is expected that main trunks would be via microwave links.

Towers would be self-supporting, to eliminate the hazard and inconvenience of guy wires. Sizing and design would allow heights of at least 300 feet to provide for paths up to 40 miles. The radio-system antennae would be far enough from the operating centre and the plant that, even with total loss of both plant and centre, the communications system could carry on emergency operations with equipment housed at the antennae base.

The communications system would be designed to serve the needs of the gas plant and associated producing operation only. Third parties, such as geophysical crews, contractors, government personnel and trappers would be accommodated only in an emergency.

Communications for pre-construction and construction activities such as surveying, gravel hauling and stockpiling would be by common carriers where available. Where the common carriers' planned or existing facilities were inadequate, the producers would approach them about extending services.

Canadian Arctic Gas Pipeline Limited, operators of the trunk line, are planning a "hot" line circuit to the producers. Therefore, no dedicated communication circuit for this purpose would be provided by the producers.

B. CONCEPTUAL DESIGN (SINGLE PLANT AND ASSOCIATED FACILITIES)

1. Operations Centre

A control centre at each gas plant would handle the control of physical equipment and the management of operating and maintenance personnel. Control of physical facilities would be by the supervisory control system, while control of personnel would be by the voice communication system.

2. Management Information

Information systems would also be needed for management of the gas plant and associated facilities. These systems would require additional computing power, since it is expected that the supervisory control system would be dedicated to process control and data acquisition.

The additional systems would include functions such as production accounting, financial reporting, and preventive maintenance. Source data would be provided from the supervisory system where applicable.

The additional computing power needed to operate these systems could be provided either on site or through a computer terminal.

3. Supervisory System

The plants' production and gathering facilities would be designed with simple process and mechanical flow. Simple local control loops would allow the process to operate within a wide range of turn-down. Therefore, a minimum amount of remote control would be needed, and the supervisory control system would be basically one for data acquisition and set-point control. For the gas plant, a limited amount of process optimization would be provided; however, any large-scale optimization programs would need additional computing power, on site or remote.

The supervisory system would embody a number of remote terminal units (RTUs) at the clusters, at the gathering system, and throughout the plant, communicating with a programmable master terminal unit (MTU) at the plant control centre. The RTUs would provide the interface with the process end devices that perform the four basic functions: alarm detection, status checking, measurement, and control. These four functions might be used in any combination at each site, and might vary in complexity depending on the specific application.

In addition to the RTUs at the clusters and within the plant area, mobile RTUs might be used to monitor weather and pollution. There would also be RTUs along the gathering system for the remote operation of block valves; these would have two low-pressure alarms, one upstream and one downstream of the block valve, to help detect and isolate leaks.

The computer-based MTU would communicate with the RTUs to gather data and transmit instructions, providing an interface between the operating personnel and the system. In addition, the MTU would be able to analyze data gathered by the RTUs, as well as perform complex functions such as making automatic well-tests, detecting pipeline leaks, generating alarm messages, and handling trend analyses, operator overrides and audits. Figure 24 depicts the supervisory control system as envisaged by the Applicants.

4. Voice and Data Communications

To provide the primary voice and data circuits, a trunking system would be used to interconnect the various sites. A main Canadian National Telecommunications (CNT) trunk would terminate at the gas plant. A PABX at the gas plant would provide the telephone services, with locals distributed throughout plant and housing as needed. Off-premises locals

would be extended to the clusters to complete the primary voice network. PABX trunks would interconnect with CNT to provide public telephone and teletype service, data circuits, and spare drops as required.

Secondary trunks would connect the gas plant and clusters. Basically, each cluster would need two circuits, one for telephone and one for data. Local clusters would be served by cable, remote clusters by VHF radio links. Supervisory data circuits would connect the master terminal unit at the gas plant to the RTUs at the clusters. In all cases, spares would be provided for future needs, or other service as might prove desirable.

A VHF repeater at the gas plant would provide area coverage for mobiles and portables. Access to the VHF system would be available from selected locations in the gas plant and housing quarters. VHF base stations at the remote clusters would handle communications among personnel and serve as backup to the telephone system. The VHF mobile system would provide communication to any other appropriate area function or staging area.

Aeronautical VHF base stations at the gas plant and at remote clusters would provide communication with aircraft.

A UHF repeater with its associated portables would furnish radio coverage within the gas plant and vicinity.

5. Aeronautical Navigation Aids

Transportation would be mainly by aircraft and helicopter. A high degree of reliability, in the face of adverse weather conditions, would be needed for operating with efficiency and safety. To this end the gas-plant landing field would be equipped with various navigational

aids that would be monitored by the supervisory system. Properly equipped aircraft could then operate under most weather conditions.

6. Recreation Systems

It would be expected that the staff should have recreational amenities, especially television. This would be provided in remote areas by a central TV translator which acts as a repeater, so long as there was an existing TV station within reach of a suitably located tower.

Besides a TV and radio distribution system, the living quarters would have an intercom and background music system. The intercom would be extended to the gas-plant area for general call and telephone backup.

C. COMMUNICATION REQUIREMENTS DURING THE CONSTRUCTION PHASE

The construction phase would require mainly telephone, teletype, and mobile radio service. Activity would centre on the gas plant and cluster sites, but would also extend to gravel deposits such as Ya-Ya Lake, and staging sites on Eskimo Lakes and river channels.

CNT trunks to the gas-plant sites would therefore be needed from the first, to provide telephone and teletype service. PABXs should be provided as well, for better immediate service and for future operations needs.

Cluster links would also be needed immediately to extend CNT telephone and teletype service from the gas plants as well as PABX locals. These links would later provide the supervisory data and telephone circuits needed for operations.

Each area would need a VHF mobile system during construction, for communications between sites, vehicles and personnel. They too would continue in use for operations.

VHF air-ground base stations would be needed at the gas plants and clusters. Navigational aids would also be used at these locations.

Recreation systems would be installed in the gas-plant living quarters during construction and continue for operations. They would require a TV translator.

It is intended that contractors should provide for their basic communications needs through commercial service from CNT. Where necessary, VHF mobile service would be provided through the gas-plant repeaters. Television coverage would be available via the translator.

D. PERSONNEL REQUIREMENTS

It is expected that once the plant and associated facilities were fully checked out and operating normally, operation and maintenance of the supervisory and communications systems could be handled by a minimum staff of four persons at each plant site:

- a computer technician
- a telecommunications technician
- an instrument technician
- an automation technical supervisor

These employees would normally work only one shift daily.

There would also be periodic visits by additional personnel for preventive and emergency maintenance functions. These visits would depend on the over-all reliability of the equipment and the capabilities of the technicians on site.

Personnel requirements for installing the supervisory and telecommunications systems could vary greatly according to the installation schedule. However, not more than ten would be involved at any given time for each gas plant and associated clusters. During the debugging stages about five persons would be needed besides the normal operating complement.

E. DEVELOPMENT SCHEDULE

Lead times required to obtain and install the supervisory and telecommunication system are long enough to warrant serious consideration in the scheduling of the project. Communications equipment is probably the most critical, since these components should be operative during the construction phases.

Installation would be coordinated with the over-all development program. For telecommunications equipment the schedule would be roughly as follows:

1. Order all equipment not later than April 1976. Prepare engineering brief and apply for licensing.
2. Pre-install camp PABX and radio gear in modules during March-May 1977, before shipping.
3. Install tower pilings at same time as those for camps (April 1976).
4. Install navigational aids and complete plant systems during September-October 1977.
5. Install cluster radio gear and links before shipment, and complete installation in fall of 1978.
6. Commission and check total system winter of 1978-1979.

This schedule should fit in with a 1979 plant completion date. The intent would be to keep field installation to a minimum by installing equipment in housings before shipment wherever possible.

Both the computer system and supervisory equipment would be needed for effective programming and testing. Scheduling for the supervisory system would be roughly as follows:

1. Specify computer and supervisory equipment by January 1976.
2. Order equipment by May 1976.

3. Begin detailed system design May 1976.
4. Accept delivery of equipment in development centre May 1977.
5. Write programs and test system in shop. Complete this by March 1978.
6. Ship equipment for installation in modules, April-June 1978.
7. Test equipment at arctic site, September 1978 - March 1979.
8. Turn system over to operations April-June 1979.

X. CONTINGENCY PLANNING

A. CONCEPTS

The Applicants have endeavoured to present a producing facility conceptual design that would meet the objectives of maximum reliability, safety, and environmental protection. Both past experience and the latest technology have been used to plan and design the system and provide it with operating flexibility. Provision has also been made as far as possible for various contingencies. Factors considered in contingency planning include: choice of sites, design, selection of equipment, construction, accommodations, automation, communications and personnel training.

The wide range of physical conditions and seasonal variation dictate specific contingency plans for the areas concerned. Initially, two process plants are proposed in the Mackenzie Delta; one is in the flood plains of the Taglu area, the other in the hilly Parsons Lake area of the Caribou Hills. General or over-all contingency plans and organization would be adapted for common situations.

Detailed contingency plans would be prepared in conjunction with final designs. They would be based on onsite investigations and detailed engineering design.

Following is a list of the type of information that would be considered in developing contingency plans for specific situations:

Access to well clusters

- roads, all-weather and temporary
- waterway navigation
- airstrips, all-weather and temporary
- elevation referenced to water levels (normal and flood)
- fill quality and quantities

Hydrological aspects from topographical consideration

- local drainage patterns
- proximity to rivers and lakes for air and water support
- flood levels during break-up and summer storms

Topographical consideration with respect to

- ground elevations at and around facilities
- ice content of soil
- ice lenses
- thickness of river and lake ice

Gathering-line route selection

- profile referenced to identifiable markers and topographic features
- access to air, water and road systems
- locations of facilities such as refrigeration units, power supply, blowdown points, camps, maintenance facilities
- river crossings, presence of permafrost
- wildlife population
- proximity of lakes and streams

Control Points

- main line valves and actuators
- corrosion inhibitors; alcohol-injection valves and their actuators
- communications facilities

B. ORGANIZATION

An over-all organizational plan to meet any contingency is shown in Figure 25. The organization would be similar to, but easier to administer, coordinate and execute than, existing operations contingency plans in exploration drilling for the Mackenzie Delta and remote northern operations. It sets out lines of authority and action to cover any contingency. The Applicants would expect to coordinate all plans through the Delta Environmental Protection Unit.

Emergency help from outside resources would be provided through contacts with other operators and the appropriate governmental agencies. The organization is shown in Figure 26. For example, an outbreak of an infectious disease at an operator's camp would be brought to the immediate attention of personnel on location, local Federal Health officials in Inuvik, and company health personnel in relevant sections of the operator's organization. A major gathering-system line break might involve not only the operator and contractor personnel, but consultation with appropriate personnel from other operators, from the Environmental Emergency Branch of the Environment Protection Service through local Department of Indian Affairs and Northern Development (DIAND) personnel, and from the Oil and Gas section of DIAND.

C. SECTIONAL PLANNING

Figures 27 and 28 refer to specific sectional contingency plans that would be developed. They include:

- a) Niglintgak Cluster and Gathering Line
- b) Taglu Well Cluster and Ancillary Facilities
- c) Parsons Lake Well Clusters, Gathering Lines and Support Facilities

Each sectional contingency plan would list the equipment, manpower and materials provided for that location, and their accessibility for each season to effect action for any particular situation. There would be some overlap of items. Sequential steps of action would also be listed.

Data assembled for each sectional contingency plan would include:

- Location of nearby equipment; i.e., vehicles, boats, aircraft, cranes, welders, and of backup equipment.

- Routing of equipment to the scene; i.e., by helicopter, barge, or road in any season.

- Location of manpower and their backup; i.e., plant and contractor personnel on site, at Inuvik or in other communities. Also a list of rotational work schedules, and the business and residential addresses and phone numbers of personnel.

- Modes of transporting manpower to equipment and then to action site; i.e., by fixed-wing aircraft, helicopter, boat or road, for any season of the year.

- Location and routing of repair supplies and materials.

- List of identifiable environmental concerns in areas of each section requiring special attention.

- Location and routing of material, manpower and equipment for clean-up operations.

- Fuel supplies and other support facilities for protracted repair and clean-up activities.

- List of local organizations, contractors, and governmental groups to call in emergency situations.

- List of personnel for specific regional government agencies such as Land Use, RCMP, Fisheries and Wildlife.

- List of air transporters, contractors and suppliers in northern and southern Canada, as backup to on-site or in-area equipment.

These specific sectional contingency plans would be regularly updated to reflect changes in facilities or personnel, new technological advances, new resource and human activities within the general work area, and the results of improved training of staff and contract personnel on site. Training programs, practice drills and in-house seminars would be scheduled to maintain a high degree of responsiveness to specific emergency calls.

D. IMPLEMENTATION

The specific sectional contingency plans would be designed to cover all construction projects and operating functions between the producing well cluster and the process plant. The contingency plan would be activated in response to any of three situations: automatic alert, manual alert, outside report.

1. Automatic Alert

Design of the field facilities would include remote automatic, local automatic, and manual operator controllers for each major item of the system, with a Central Control Room for monitoring coverage in the Operations Centre.

Subsurface and surface control valves would be located at each well. They would be hydraulically operated to shut in wells automatically or by remote control at need. Individual well-flow conditions would be monitored continually. Ancillary controls on the methanol-injection, refrigerating (where required), and corrosion-inhibitor systems would also be monitored.

A line failure between producing well and test module would be indicated by reduced line pressure and a change in temperature and flow rate. Under such conditions the surface and subsurface control valves would close automatically, as would also the Flow Rate Control valve, thus isolating the section. The same would happen in the event of a gathering-line failure.

This initial automatic response to an emergency situation would be the first line of defence. Personnel on duty would then advise the Operations Superintendent who would take charge. He would proceed with the necessary action outlined below:

- Dispatch an investigation team to the site.
- Ensure that the emergency has been stopped.
- Ensure that aid is sent to the personnel involved.
- Report to the appropriate personnel; i.e., the operations manager; government agencies with specific interest; operating and contract personnel (who would remain on standby until the situation had been completely assessed).

2. Manual Alert

A manual alert could occur in any operations area. It could be a case of equipment wear reported by the operating and maintenance personnel through their normal duties. It could involve equipment operation, personnel health, or possibly abnormal climatic conditions such as a flood threat. Any such occurrence would necessitate an alert to stand by for remedial steps.

3. Outside Alert

In the remote event of a local or national development that affects the operations system, an outside source might advise the Operations Superintendent to call or be prepared to call a system shutdown.

4. Assessment of Damage

On arrival at the scene of an emergency, the site investigation crew would make the necessary observations and report to the Operations Superintendent. These observations would include reports on

- personnel safety
- extent of damage to site
- environmental effects, if any
- specific nature of terrain involved
- wildlife effects
- weather conditions

The Operations Superintendent would then assess the situation and dispatch appropriate equipment, personnel and materials to effect repairs and restore the situation to normal. He would then notify appropriate company, government and other personnel of the action taken.

Except in areas where all-weather roads with parallel gathering lines are planned to well sites, transportation methods would vary with the topography and the season, and might involve more than one type. For example, equipment, crews and repair materials for a well cluster would be transported in winter along permanent or winter roads, or by STOL aircraft or helicopter. In summer, boats, all-terrain vehicles, STOL aircraft on floats or helicopters would serve.

During the construction phase, work would be arranged for access to the sites with the least possible disturbance of the environment. For example, winter construction on ice and snow-packed roads paralleling the gathering line rights-of-way would protect the terrain against damage from heavy equipment. Wildlife activities would be considered and construction scheduled accordingly.

5. Materials and Supplies

Each wellsite cluster would be provided with emergency accommodation, possibly including a bunkroom, standby power unit and heat, and emergency rations. All transportation equipment would be able to communicate with the Operations Centre.

Warehousing would be provided for the stocks of maintenance and repair items considered necessary for a remote operation. Stocks would include items such as portable welding and light units, spare pipe and insulating material for possible line breaks, and spare valves, controllers, pumps, fittings and tools.

6. Reporting

As already described, predetermined sequential steps for emergencies would be listed in each sectional contingency plan. Included also would be the various reporting actions to ensure that the proper steps were carried out.

The first report would be made by the observer to the Operations Superintendent. The second report would establish and open communication lines with on-site investigators, the Operations Manager, and appropriate government-agency representatives. The third report would describe the action planned and taken.

A final, comprehensive report would then be prepared by the Operations Superintendent for submission to management, relevant government personnel, and other operators. This report would discuss the cause, effect, action, timing and environmental effect, if any. It would also provide for corrective action to preclude similar occurrences.

E. Facilities and Equipment

A contingency plan would be remiss if it failed to evaluate the facilities, equipment and personnel involved in construction and operation so that complete coverage could be planned. Future technological developments would necessitate revisions not only in the equipment selected but also in the contingency plans to cover it.

In the final design phase, material-handling, availability and maintenance specifications would be considered for each section. The probability of equipment failure and its effect on the environment would be evaluated, to be sure that the best equipment was chosen for each set of conditions.

In selecting campsites, the terrain (drainage and flood considerations), the distance to work sites, waste-disposal methods, the types of camp for different personnel, and the number of camps would all be taken into account. The plan would aim at maximum human safety from hazards such as fire, exposure and disease.

Defense or backup would occasionally be provided for contingency against equipment failure. For example, for fuel storage the first line of defense would be a properly specified tank. The second line would be a dyke, designed and built to hold the fuel against leakage and with a capacity greater than the total volume of the enclosed tanks. The third line would be the choice of a site where, should any fuel happen to escape the dyke, equipment and material would be available to prevent a natural disaster. Often the defense provided for one contingency would serve others as well. For example: a dyke around fuel storage would not only keep fuel in, but keep ground fires out. A cluster pad built to minimize tundra disturbance would both keep out ground fires and prevent flooding and possible ice damage near rivers.

Proper selection of aircraft navigational aids and communications systems would both reduce flight hazards in unseasonable flying weather, and give up-to-date information with respect to weather changes and ground conditions. These aids would also speed the arrival of investigation crews and personnel at the scenes of emergencies, so that remedial action could be taken sooner.

F. Personnel

Consideration of individual backgrounds, attitudes and job expectations would improve the chances for maximum human safety and system reliability. Workers would be trained for work in remote areas. They would be instructed in first aid and survival, and given proper training in equipment processing and handling before being assigned to their jobs. For example, workmen using hand tools would be checked to make sure that they handled them safely. All workers would be taught the proper use of communications systems. Work permits would be explained, and would be required for hazardous areas.

"Pre-work" or "pre-construction" meetings at the start of each separate project would ensure that all personnel understood the project, their job requirements, their roles in the project, any hazards associated with their work area or any other area in the vicinity, and any rules or regulations covering the work site, travel area and camp. For each activity, the environmental effect would be considered.

Key personnel in these projects would be identified to ensure proper communication links.

On-the-job training, in-house seminars and information exchanges with other operators and related government agencies would be scheduled. Special courses also would be held to develop the expertise needed for the highest reliability of system operations, during both construction and operating phases.

TABLE I
BASIC DESIGN CRITERIA

	<u>Parsons Lake</u>	<u>Taglu</u>	<u>Niglintgak</u>
<u>Well Production</u>			
Flow Rates (MMCFD)	10-80	10-50	10-50
Shut-in wellhead pressure (psig)	3400	3600	2500
<u>Gathering-line Conditions</u>			
Flow rates (MMCFD)	125-250	10-50	250-500
Pressure (psig)	1400	3300	1350
<u>Weather Conditions</u>			
Temperature (°F)	-60-100	-60-100	-60-100
Winds (mph)	up to 60	up to 60	up to 60
<u>Major Roads*</u>			
Width (feet)	35	35	-
Gravel thickness (feet)	5-7	5-7	-
<u>Minor Roads**</u>			
Width (feet)	20	-	-
Gravel thickness (feet)	4	-	-
<u>Airstrips</u>			
Length (feet)	6500	2500	-
Width (feet)	390	200	-

*for heavy-module transportation

**for cluster access

TABLE II

MANPOWER REQUIREMENTS FOR CONSTRUCTION OF
MACKENZIE DELTA GAS-GATHERING SYSTEMS

		Approximate Activity Intensity (Man-Months)
1.	<u>Parsons Lake</u>	
	Construct winter roads	40
	Install piles for pipeline supports	50
	Install pipeline supports on piles	30
	Build pipeline and test	70
	TOTAL	190
2.	<u>Taglu-Niglintgak</u>	
	Construct winter roads	25
	Install piles for pipeline support and valve modules	100
	Install pipeline supports on piles	30
	Build pipeline, river crossings and test	150
	TOTAL	305

TABLE III

MAJOR CONSTRUCTION EQUIPMENT FOR
GATHERING SYSTEM

<u>Description</u>	<u>Approximate Number</u>
Bulldozers	3
Front-end Loader	3
1-1/2-yd Clam	1
1-1/2-yd Backhoe	2
Graders	3
3/4-ton Pick-up Trucks	7
1-1/2-ton Trucks	3
19,000-lb. Trucks	8
3-ton Dump Trucks	6
5-ton Flatbed Trucks	6
10-yd. Dump Trucks	8
20-yd. Dump Trucks	4
48-Passenger Bus	2
Office Trailer	1
Shop and Warehouse	2
Welders	15
Ambulance	1
Generators	12
Tractor and 45' Semi	2
6-ton Hicab Crane	8
15-ton Cranes	6
35-ton Cranes	2
Tamper	2
Trencher	1
Air Compressor	5
Boring Machines	8
Light Plants	7
Welding Tents	12

FIGURE 1

GATHERING SYSTEM AND GAS ARCTIC PIPELINE LOCATION

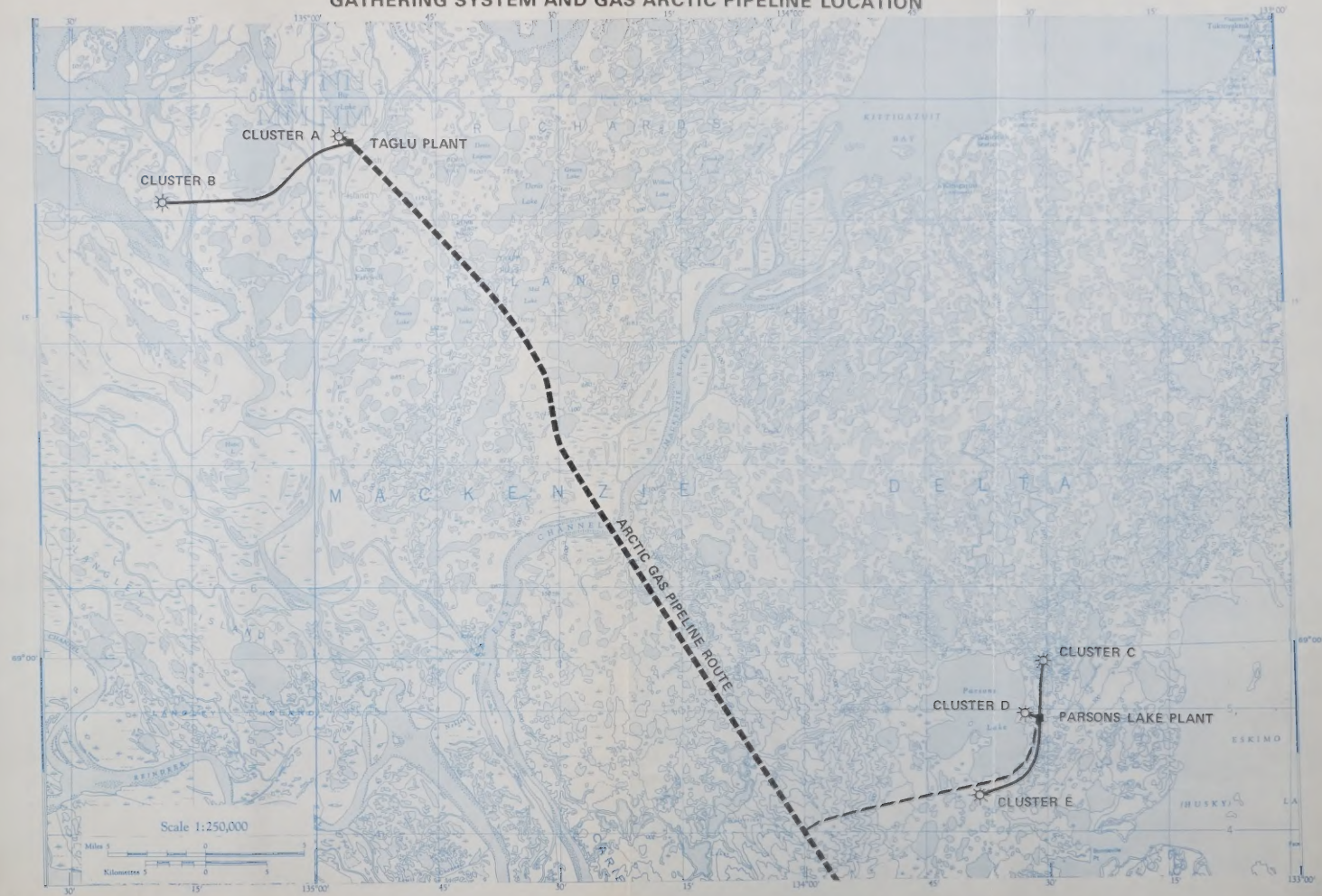


FIGURE 2

CONCEPTUAL LAYOUT - WELL CLUSTER PRODUCTION FACILITIES

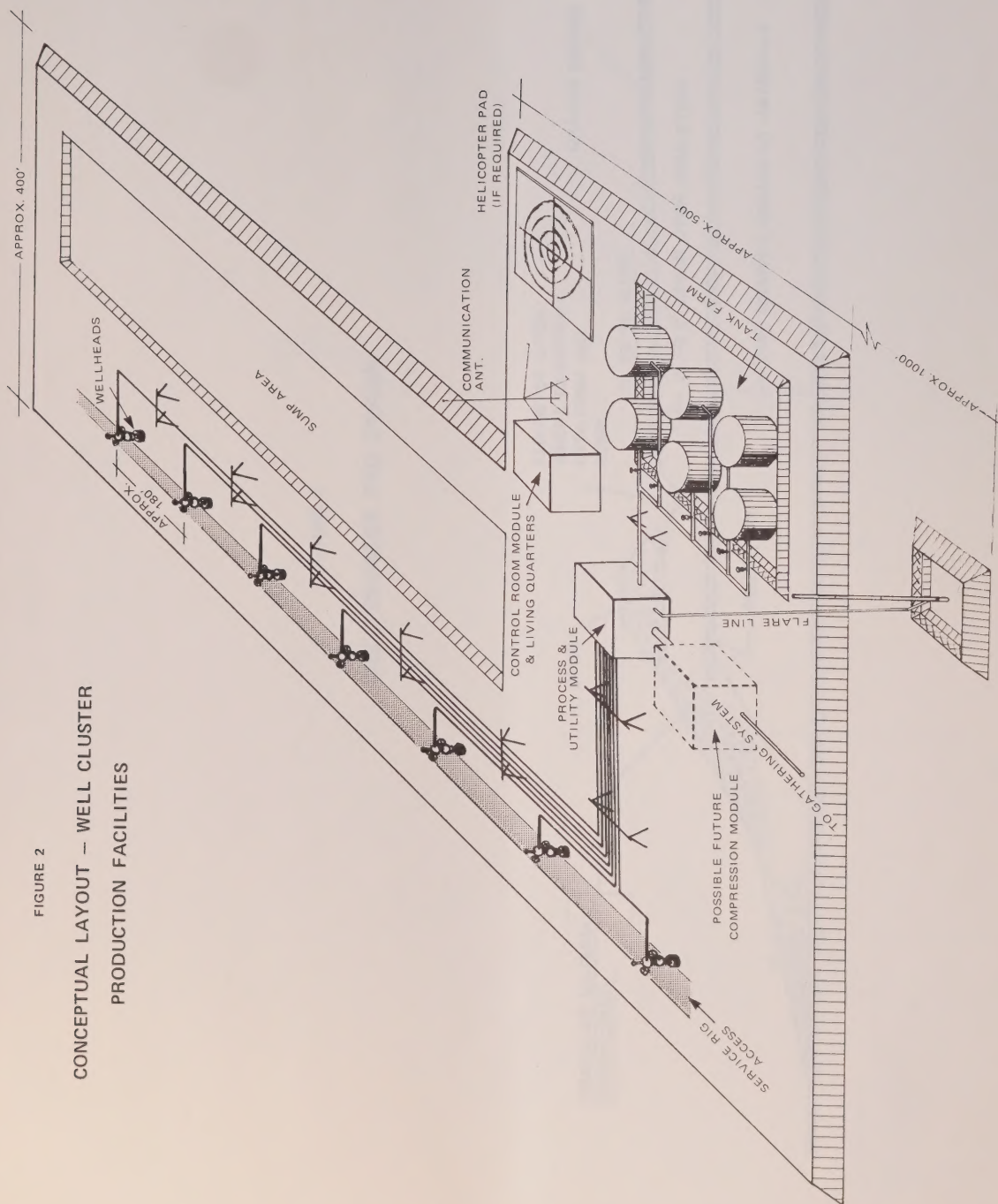


FIGURE 3

WELL CLUSTER PAD DESIGN

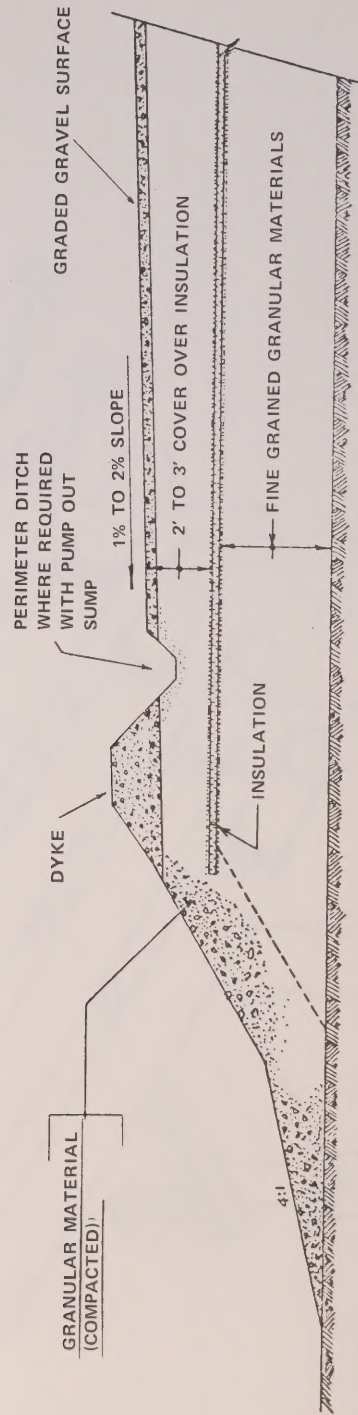


FIGURE 4

CONCEPTUAL PIPE SUPPORT
CLUSTER PAD FLOWLINES

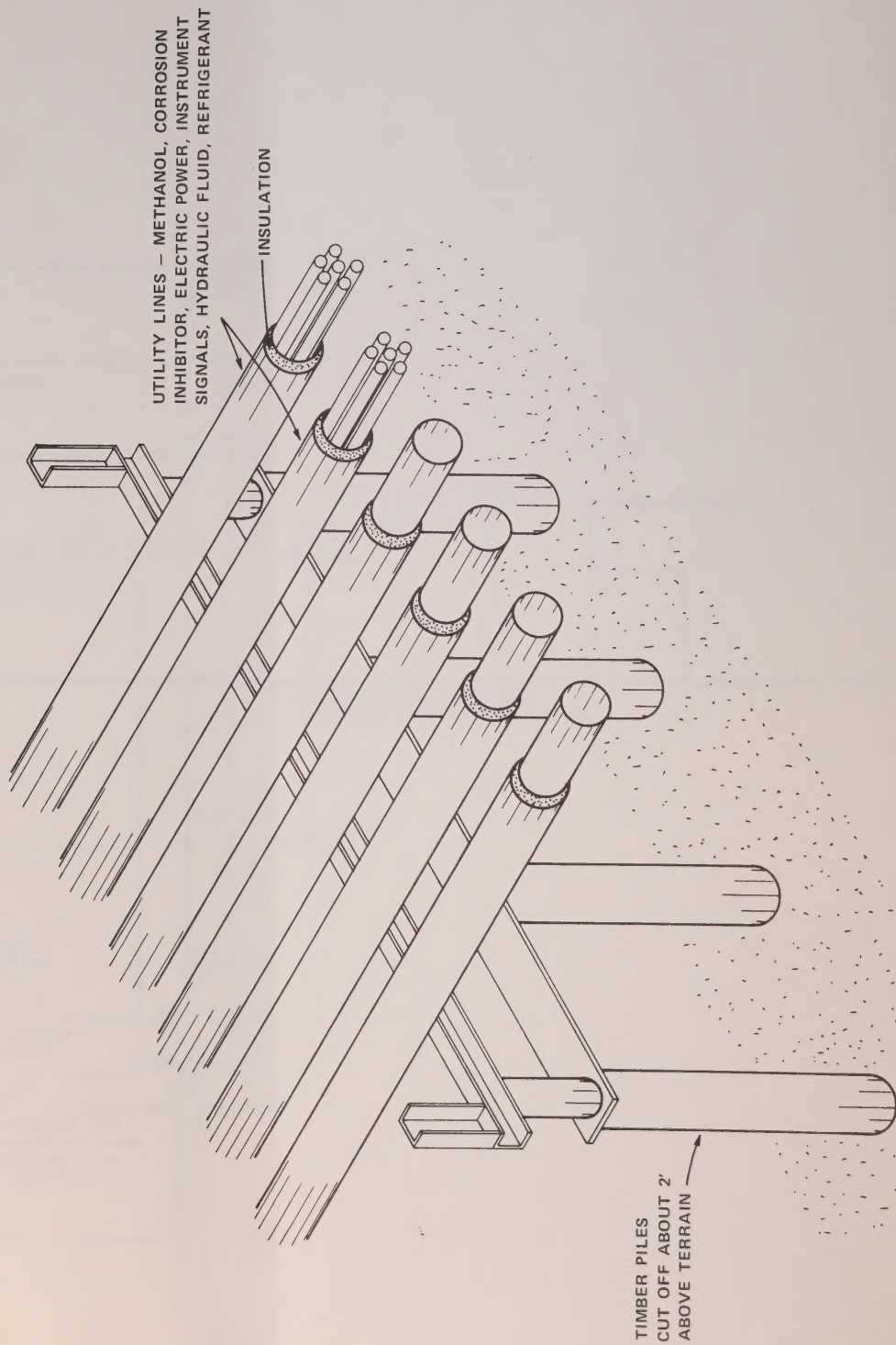


FIGURE 5

FLOW DIAGRAM - TAGLU WELL CLUSTER "A"

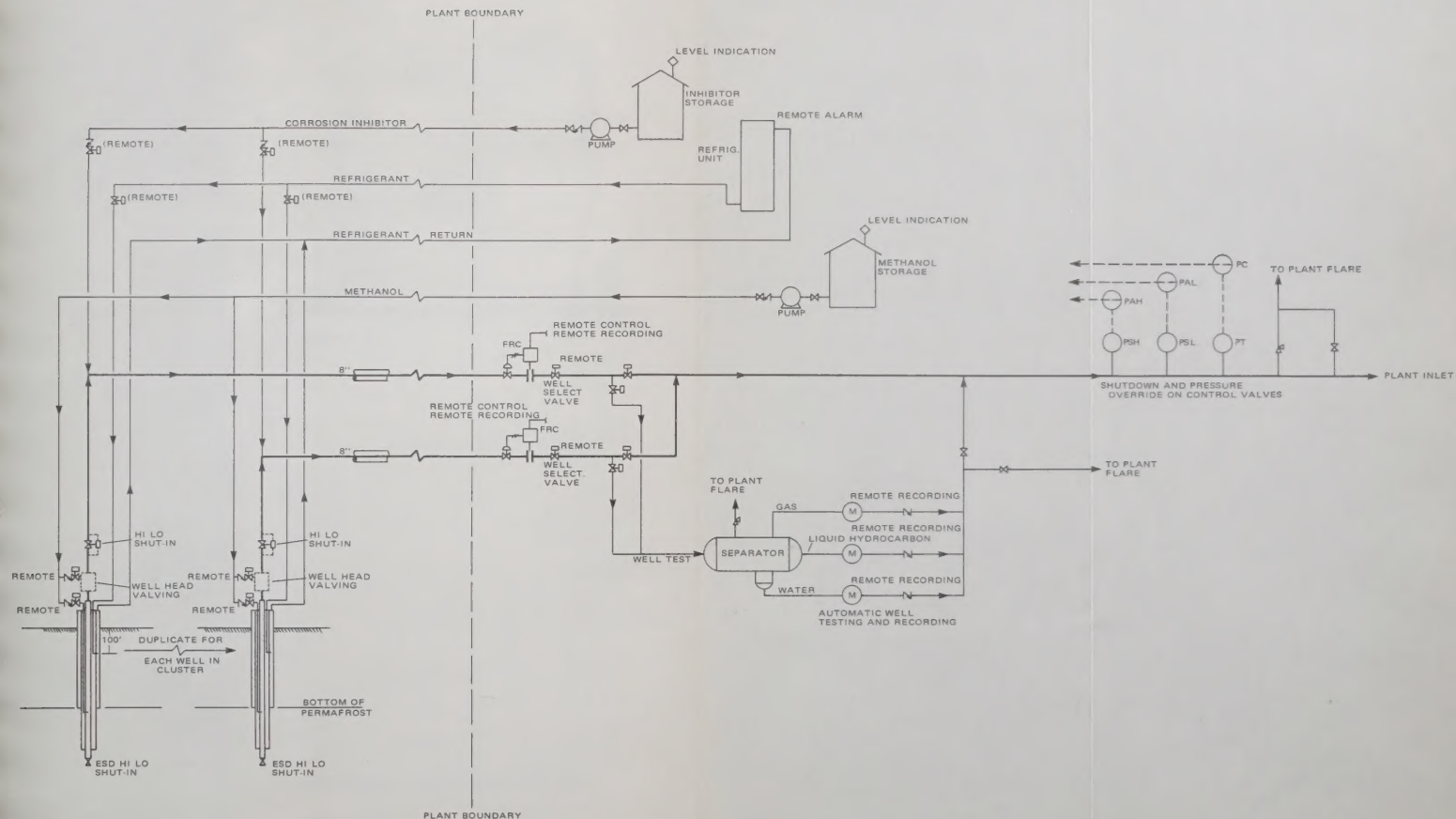
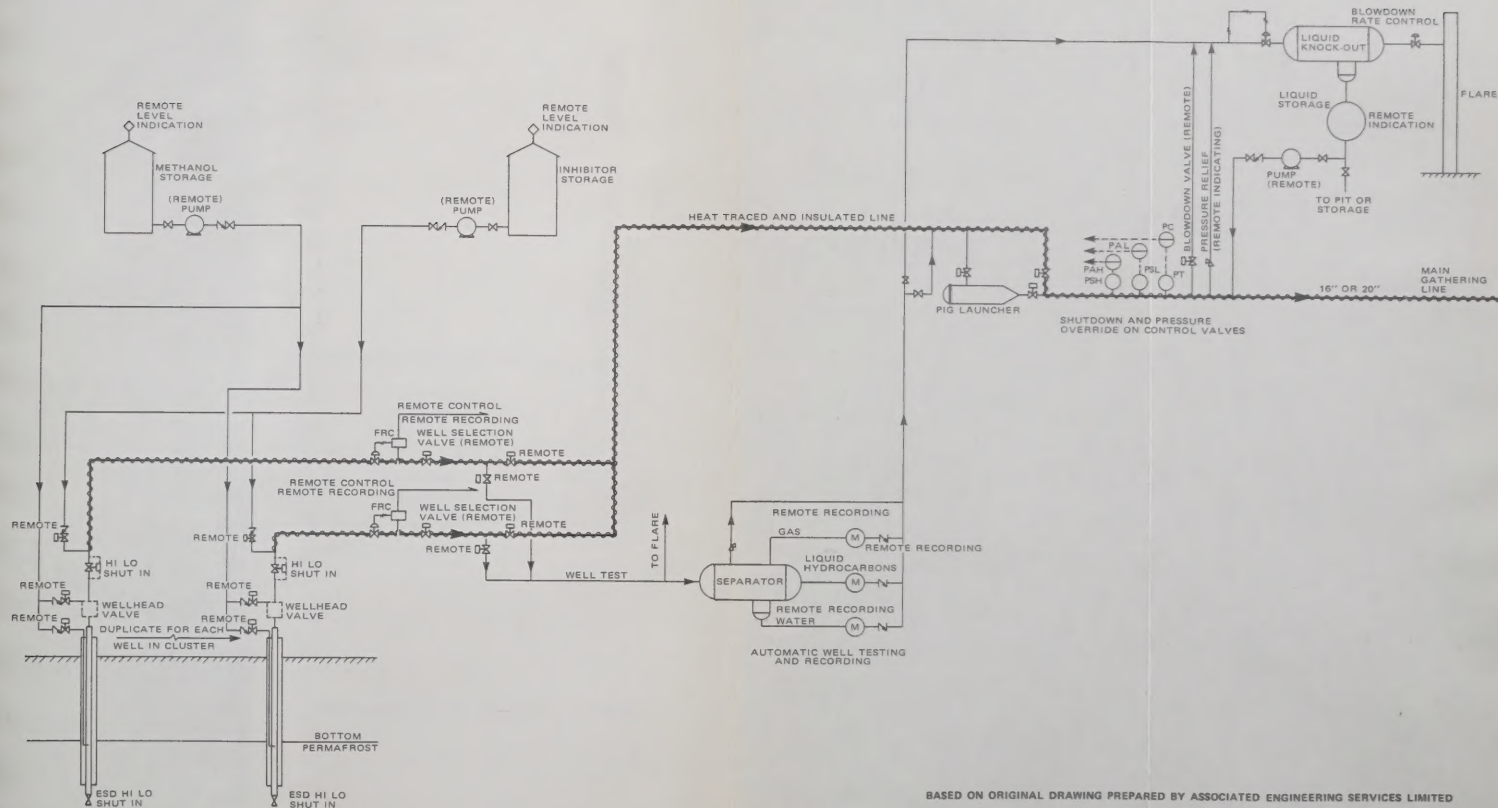


FIGURE 6

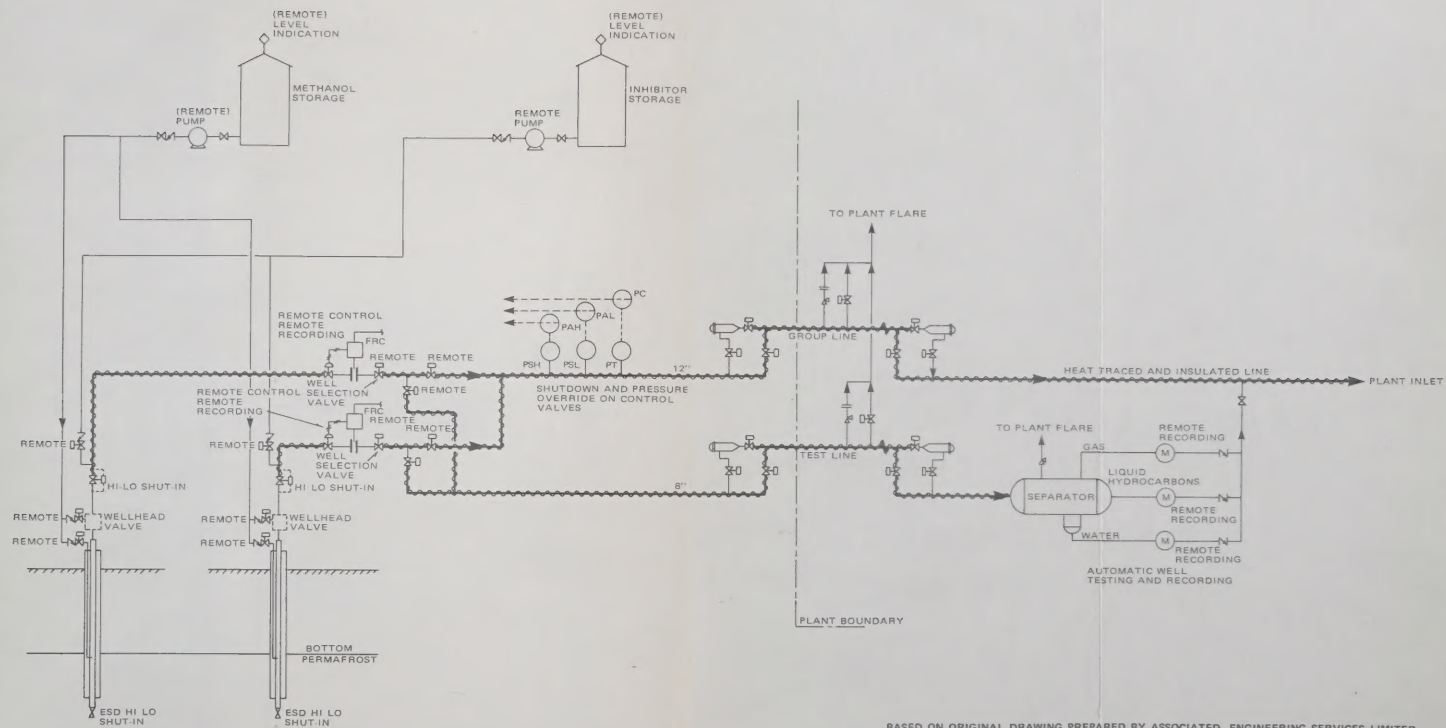
FLOW DIAGRAM - NIGLINTGAK "B", PARSONS LAKE "C" AND PARSONS LAKE "E" CLUSTERS



BASED ON ORIGINAL DRAWING PREPARED BY ASSOCIATED ENGINEERING SERVICES LIMITED

FIGURE 7

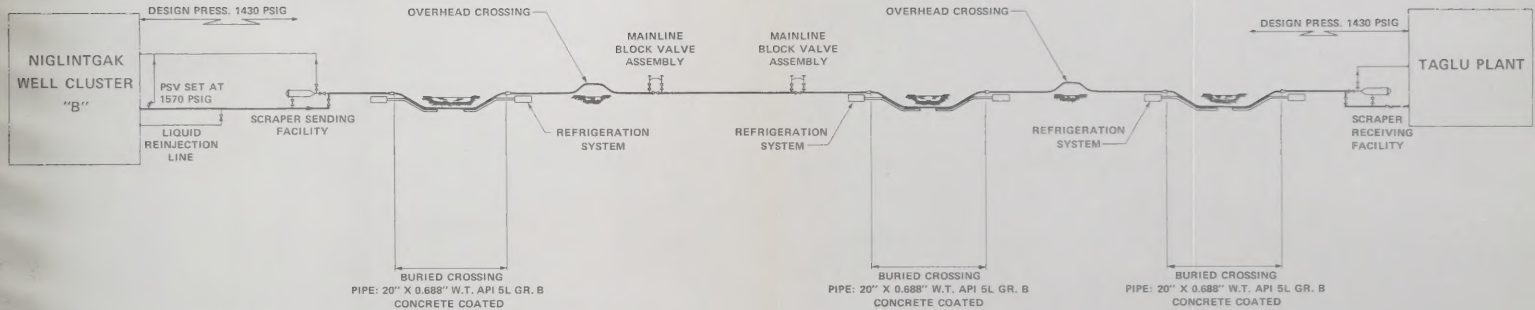
FLOW DIAGRAM - PARSONS LAKE CLUSTER "D"



BASED ON ORIGINAL DRAWING PREPARED BY ASSOCIATED ENGINEERING SERVICES LIMITED

FIGURE 8

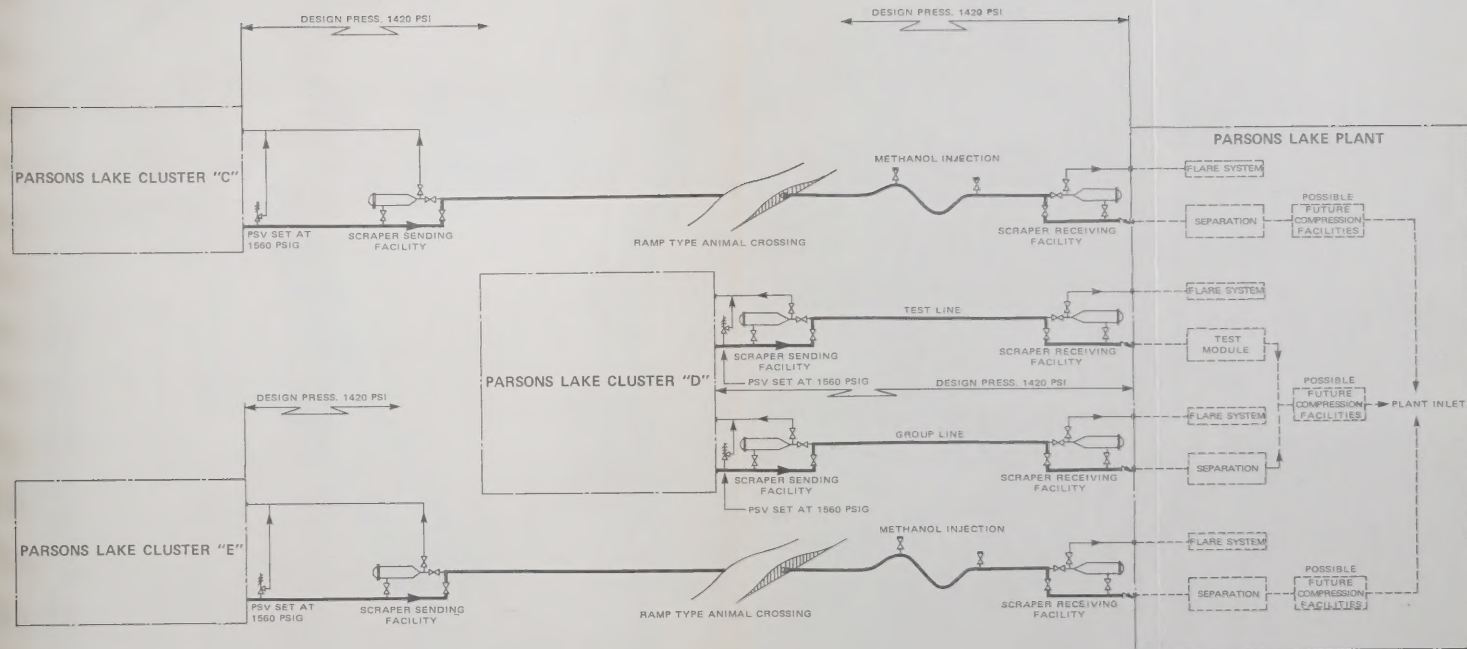
SYSTEM SCHEMATIC
NIGLINTGAK - TAGLU GATHERING SYSTEM



BASED ON ORIGINAL DRAWING PREPARED BY
ASSOCIATED ENGINEERING SERVICES LIMITED

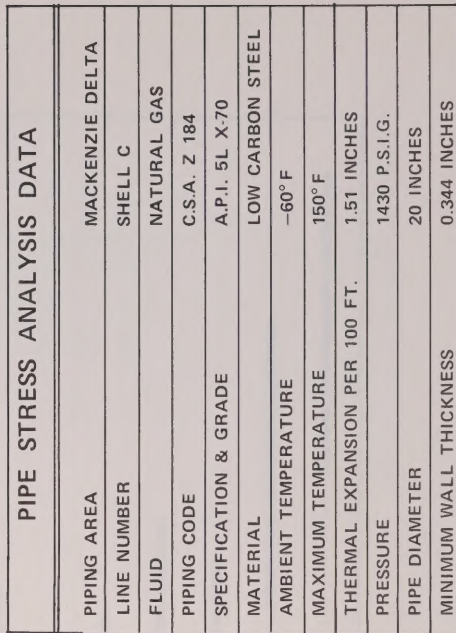
FIGURE 9

SYSTEM SCHEMATIC PARSONS LAKE GATHERING SYSTEM



BASED ON ORIGINAL DRAWING PREPARED BY
ASSOCIATED ENGINEERING SERVICES LIMITED

NIGLINTGAK – TAGLU GATHERING LINE TYPICAL EXPANSION AND SUPPORT CONFIGURATION



BASED ON ORIGINAL DRAWING PREPARED BY ASSOCIATED
ENGINEERING SERVICES LIMITED

FIGURE 11

PIPELINE ACTIVITIES – PARSONS LAKE

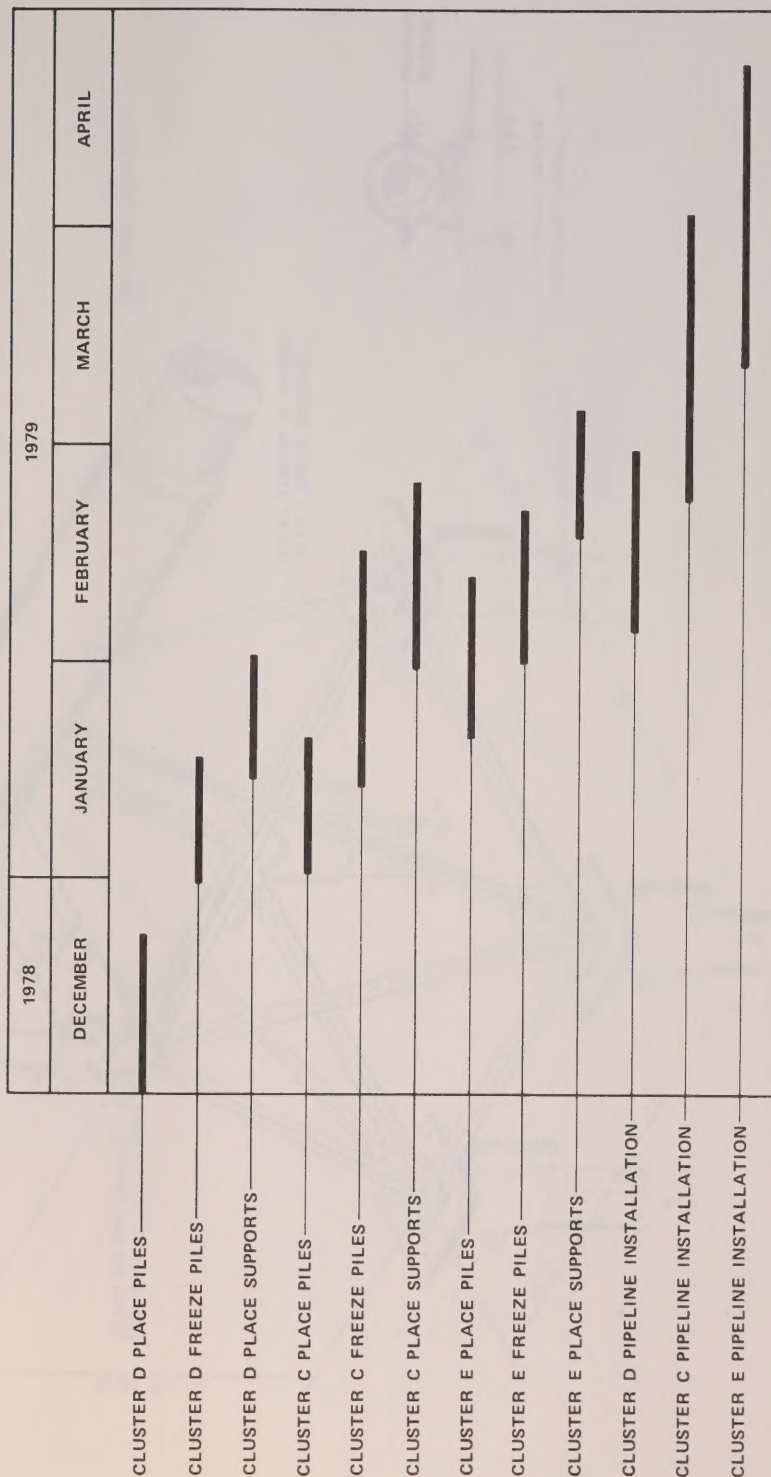
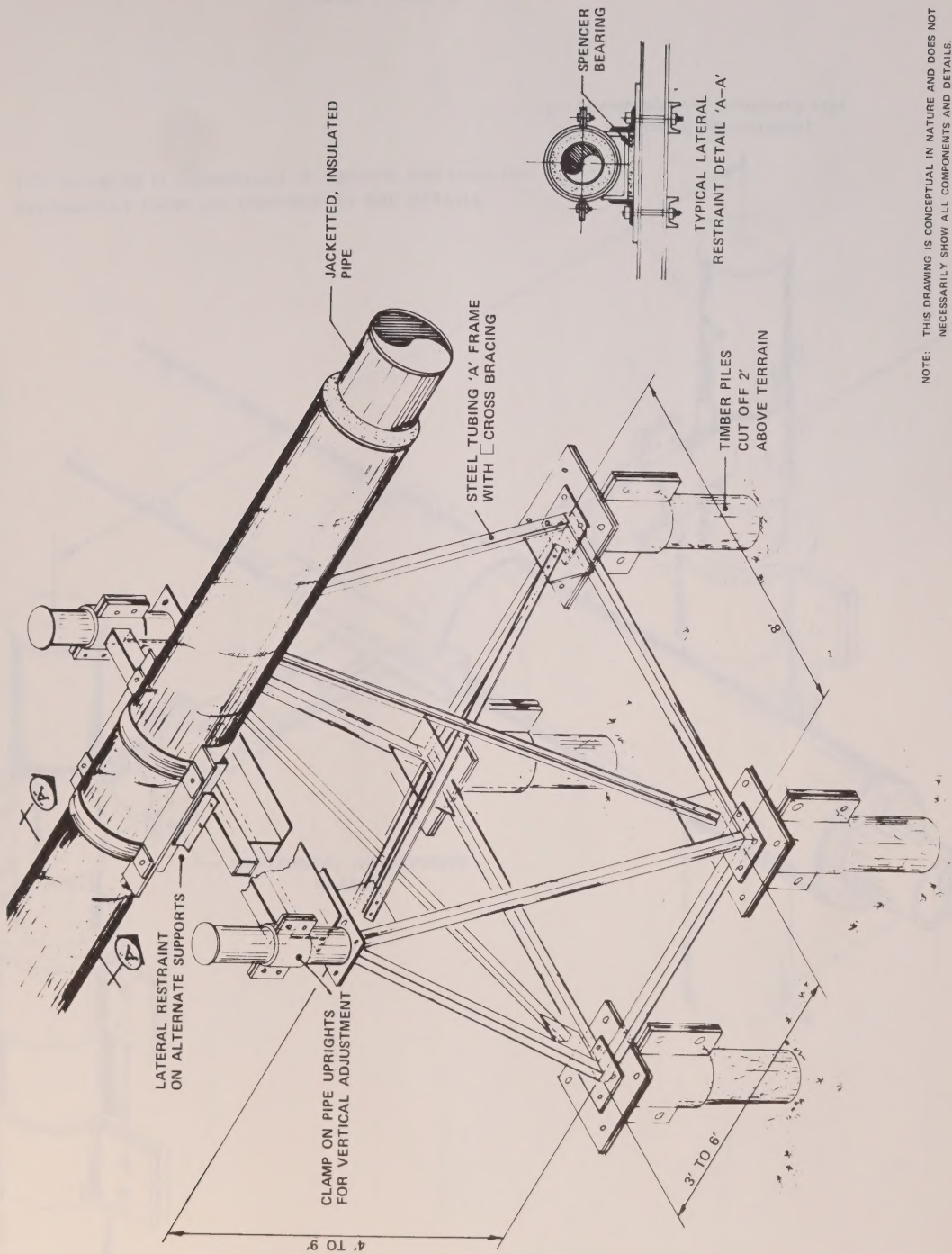


FIGURE 12

LATERAL RESTRAINT PIPE SUPPORT 4' TO 9'

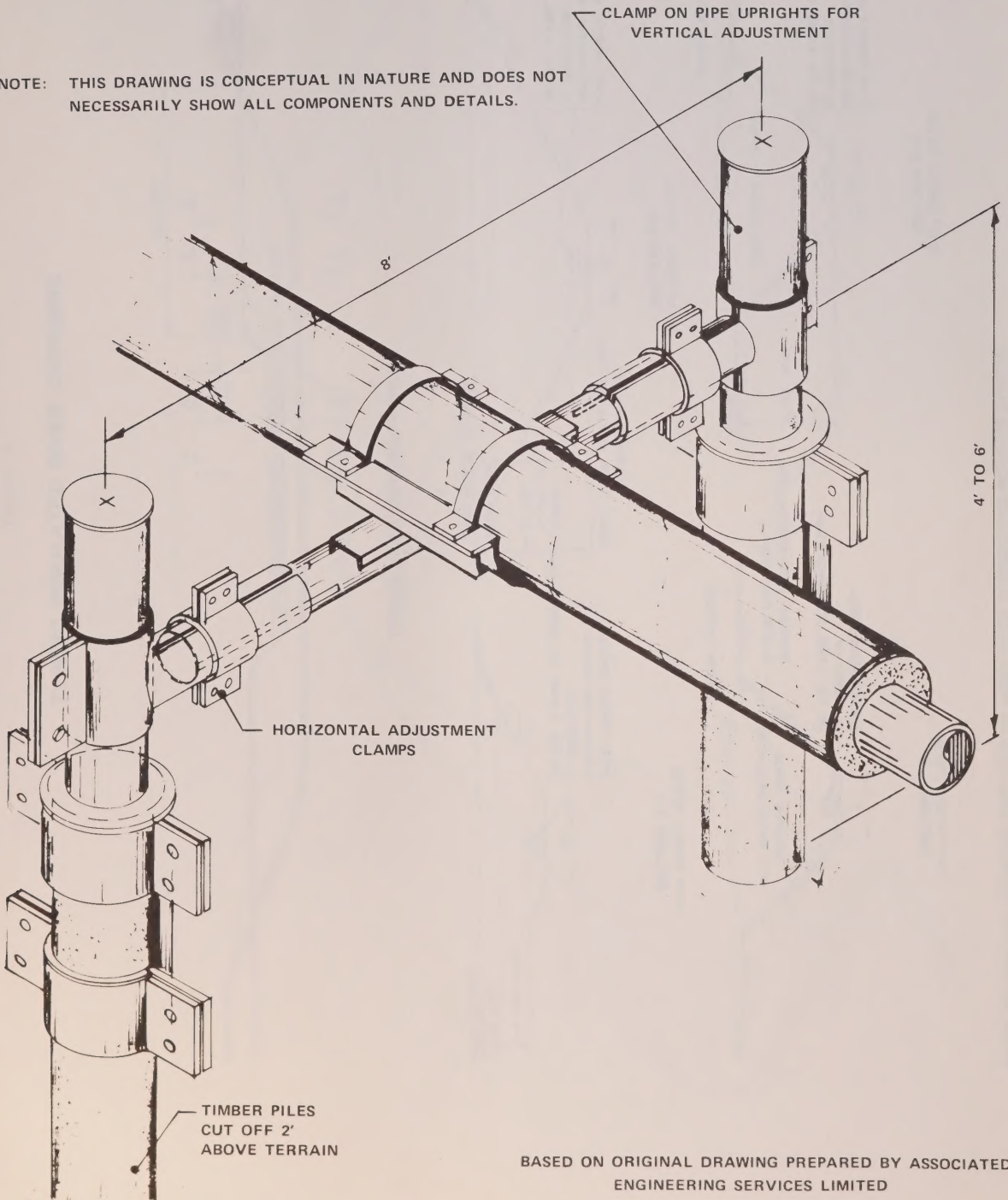


NOTE: THIS DRAWING IS CONCEPTUAL IN NATURE AND DOES NOT
NECESSARILY SHOW ALL COMPONENTS AND DETAILS.

FIGURE 13

UNRESTRAINED PIPE SUPPORT
LESS THAN 6'

NOTE: THIS DRAWING IS CONCEPTUAL IN NATURE AND DOES NOT
NECESSARILY SHOW ALL COMPONENTS AND DETAILS.



BASED ON ORIGINAL DRAWING PREPARED BY ASSOCIATED
ENGINEERING SERVICES LIMITED

TYPICAL INSULATED RIVER CROSSING

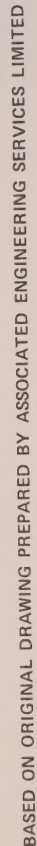


FIGURE 15

CONCEPTUAL ARCH TYPE RIVER CROSSING

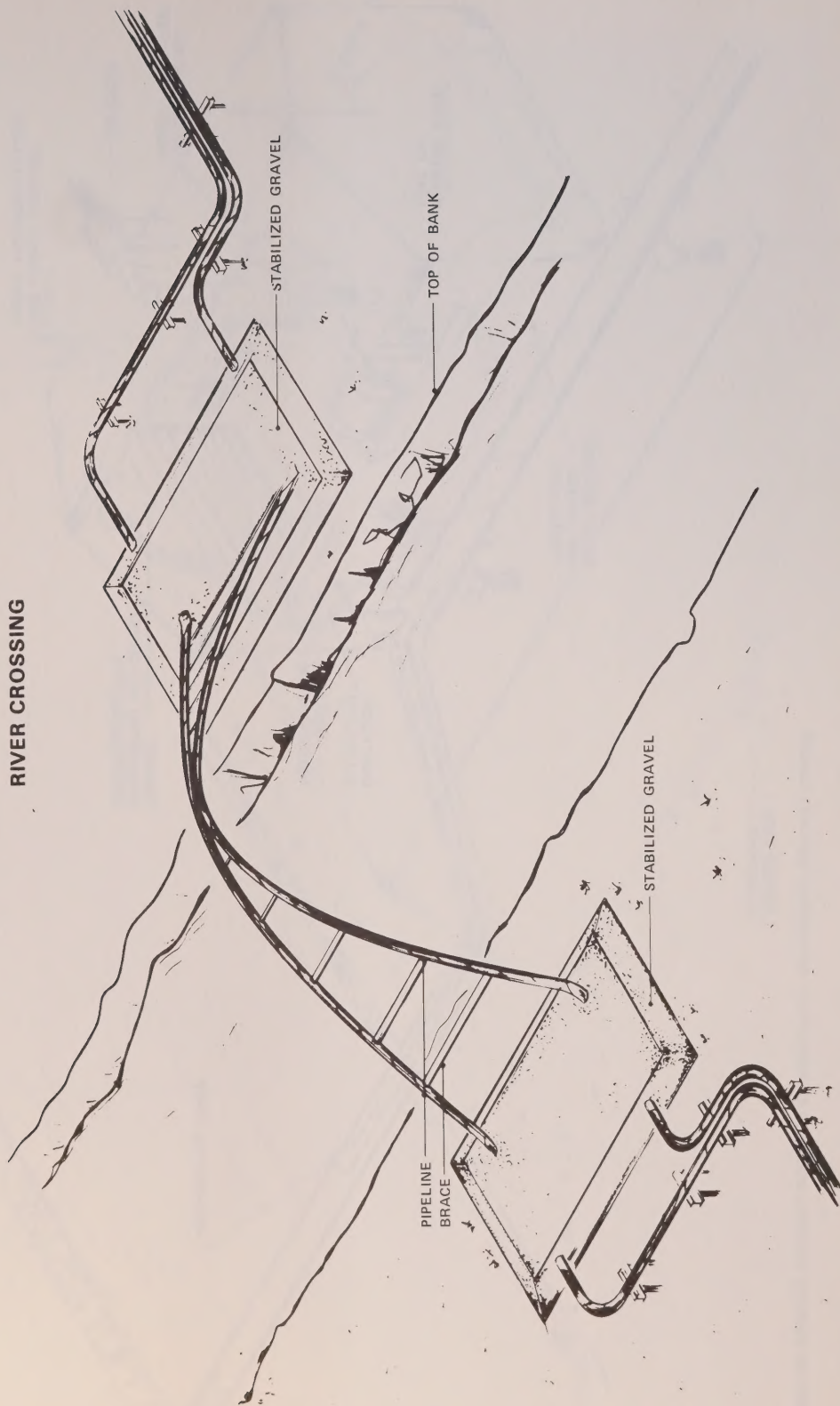
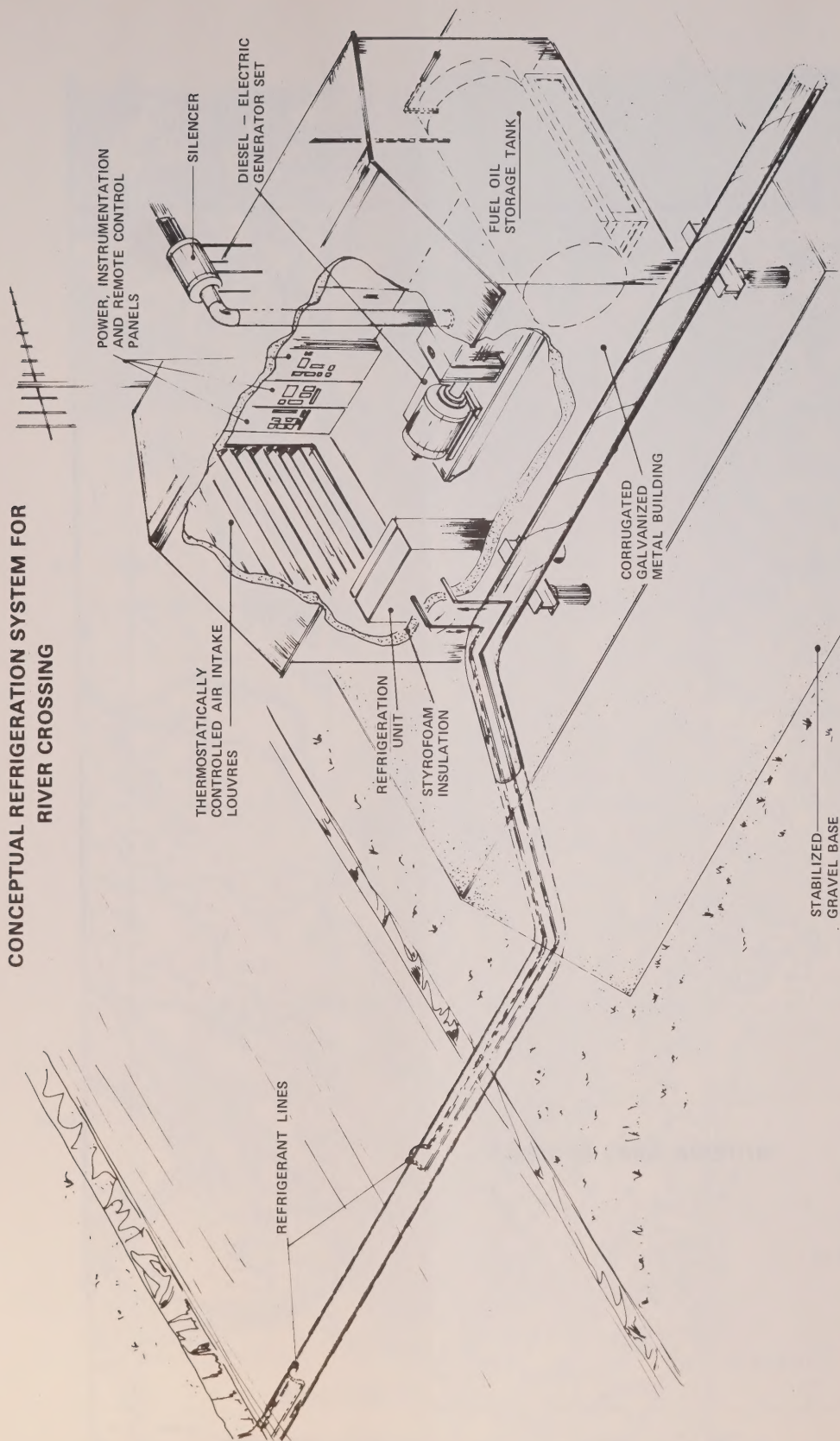


FIGURE 16

CONCEPTUAL REFRIGERATION SYSTEM FOR RIVER CROSSING



BASED ON ORIGINAL DRAWING PREPARED BY ASSOCIATED ENGINEERING SERVICES LIMITED

FIGURE 17

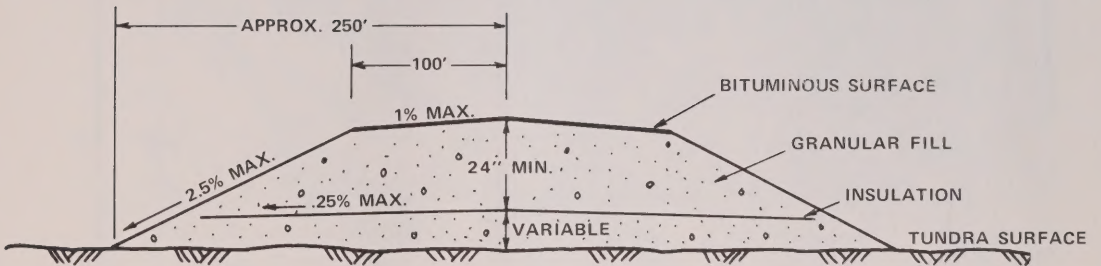
AIRSTRIP LOCATION MAP



FIGURE 18

AIRSTRIIP CROSS SECTION

PARSONS LAKE



TAGLU

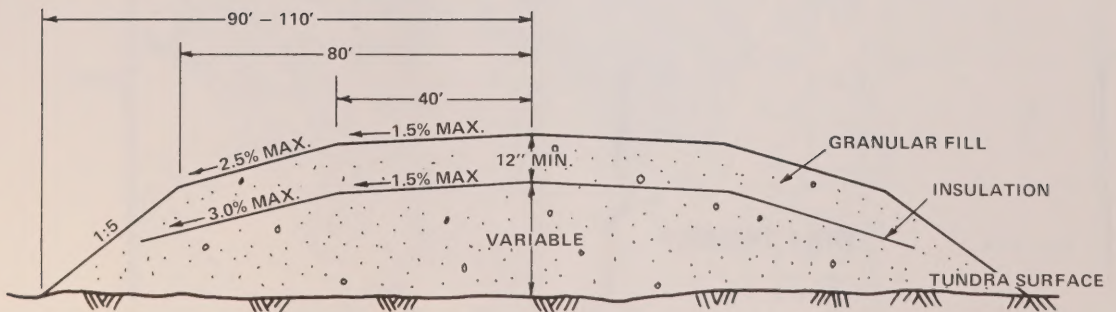


FIGURE 19

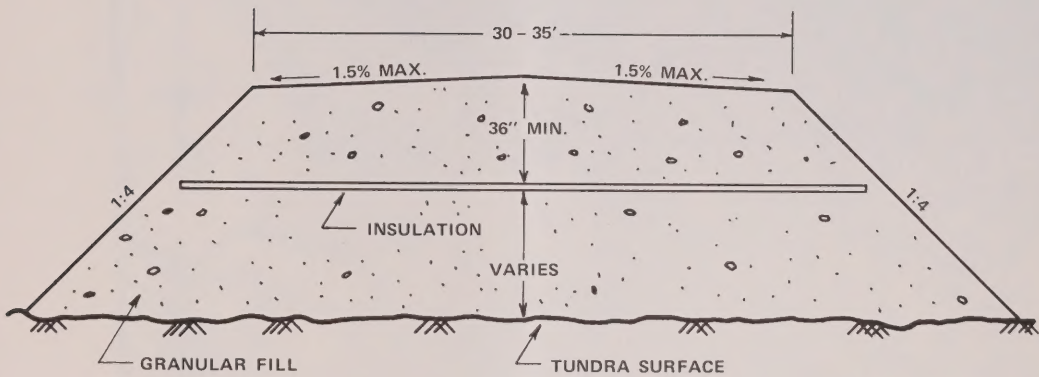
ROAD LOCATION MAP



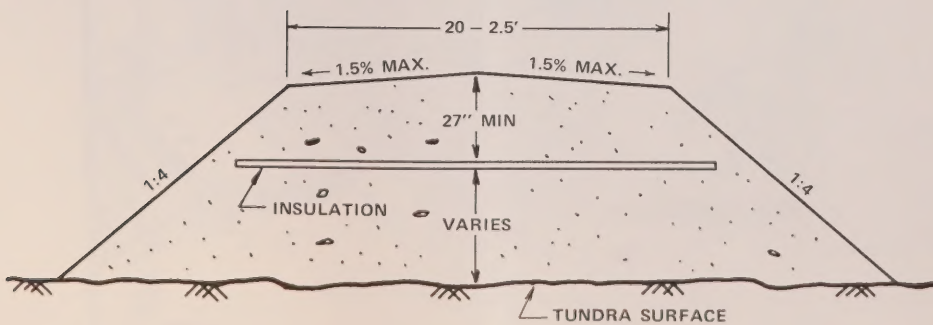
FIGURE 20

ROAD CROSS SECTION

TRANSPORTER ACCESS ROADS



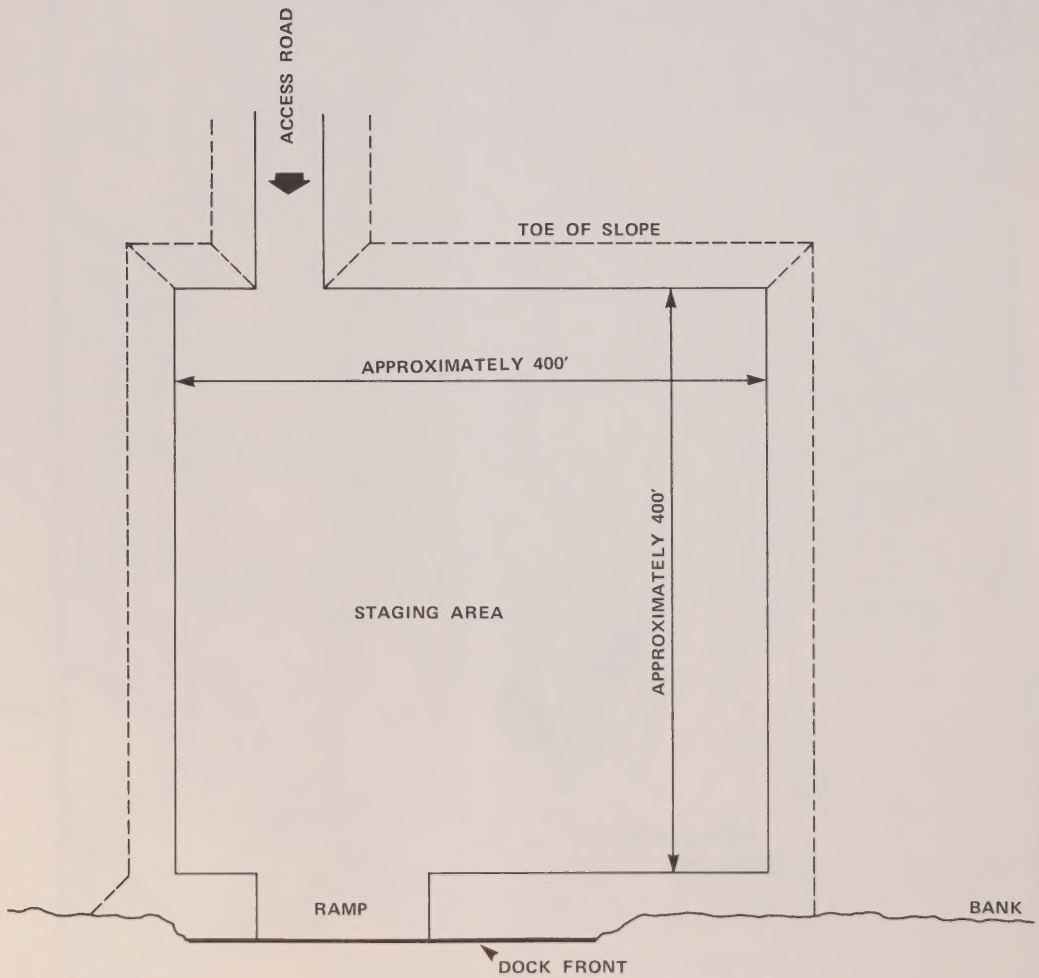
SECONDARY ACCESS ROADS



DOCK LOCATION MAP

FIGURE 22

CONCEPTUAL DOCK AND STAGING AREA
PLAN LAYOUT



MATERIAL SOURCE LOCATIONS

FIGURE 24

SUPERVISORY CONTROL SYSTEM

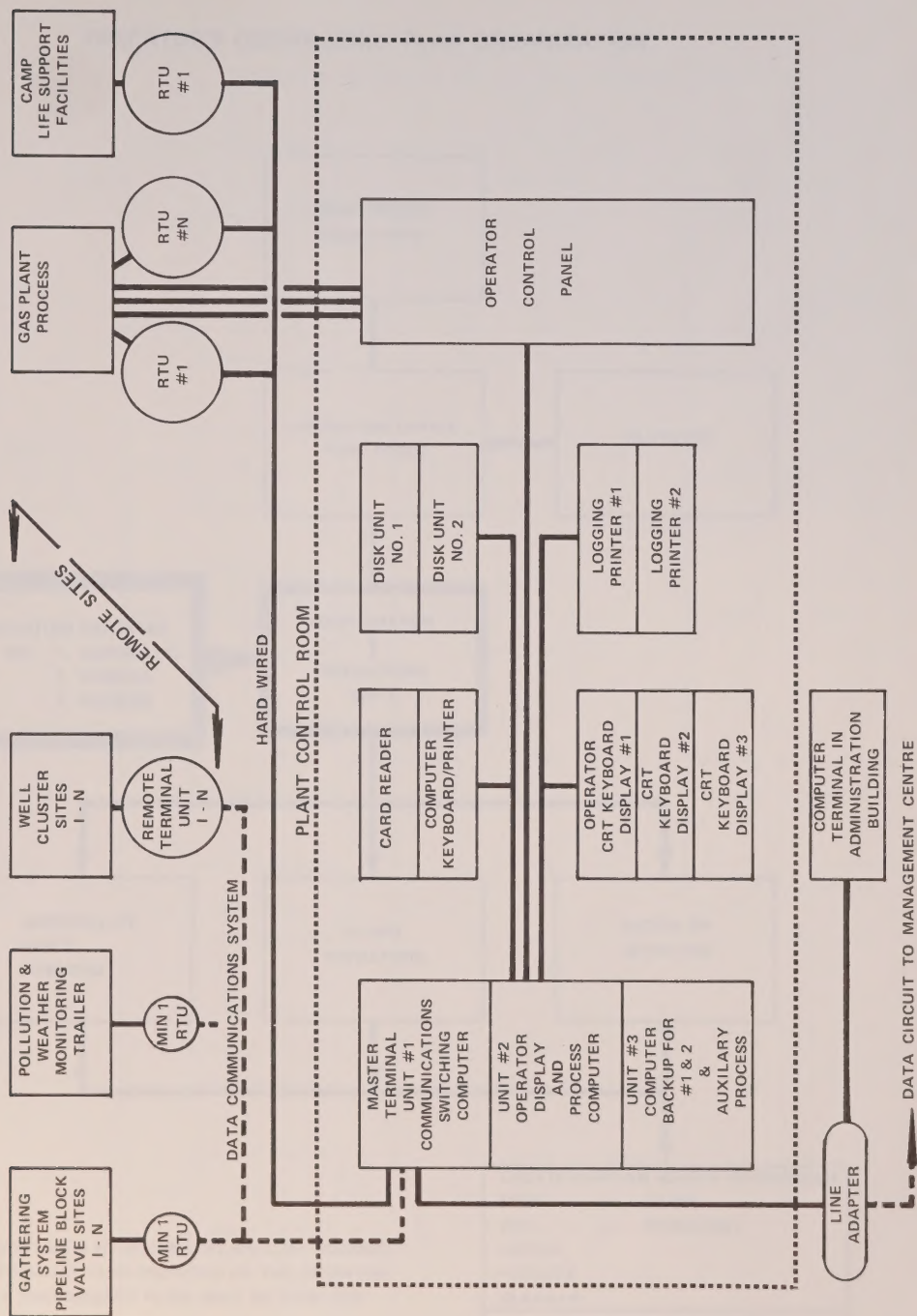
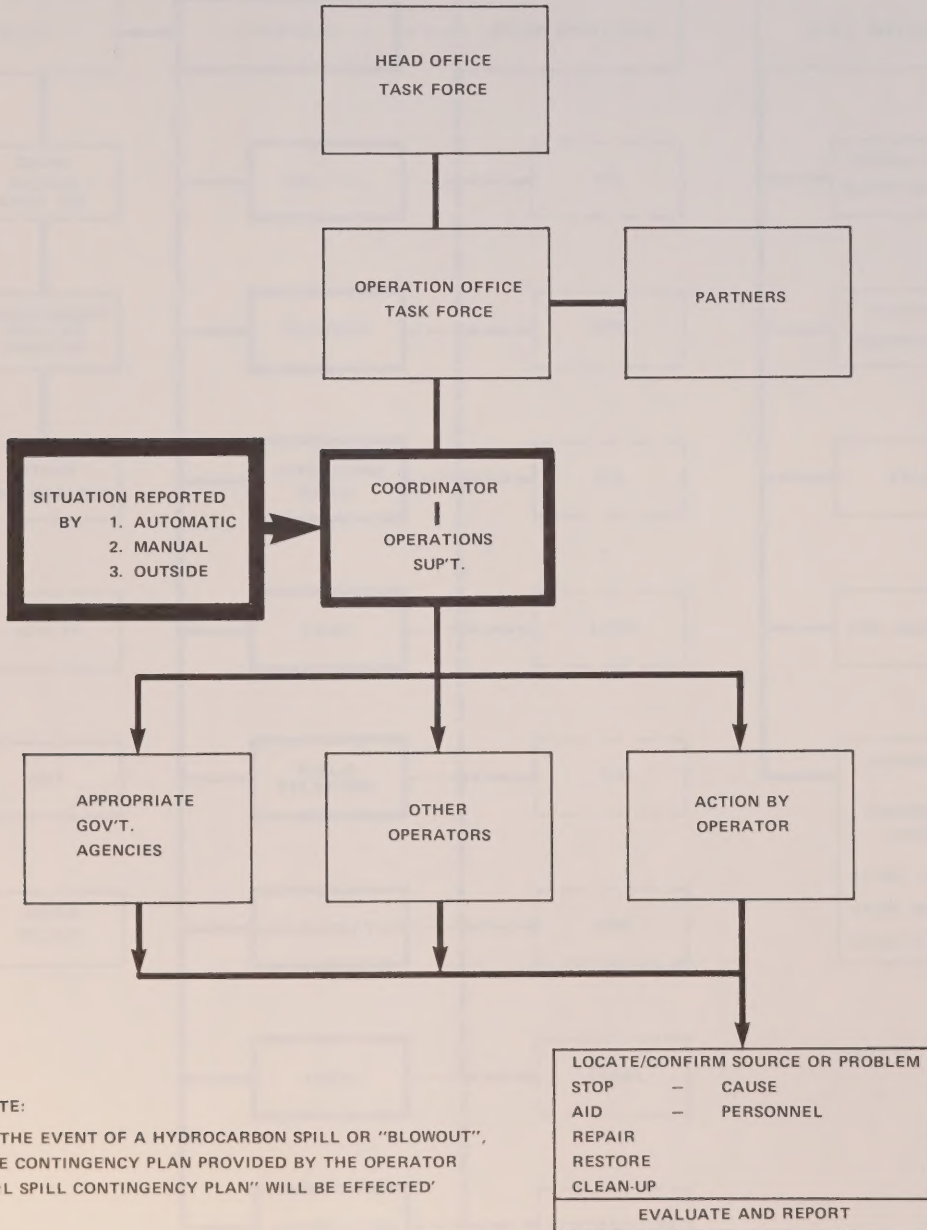


FIGURE 25

OPERATOR'S CONTINGENCY PLAN ORGANIZATION

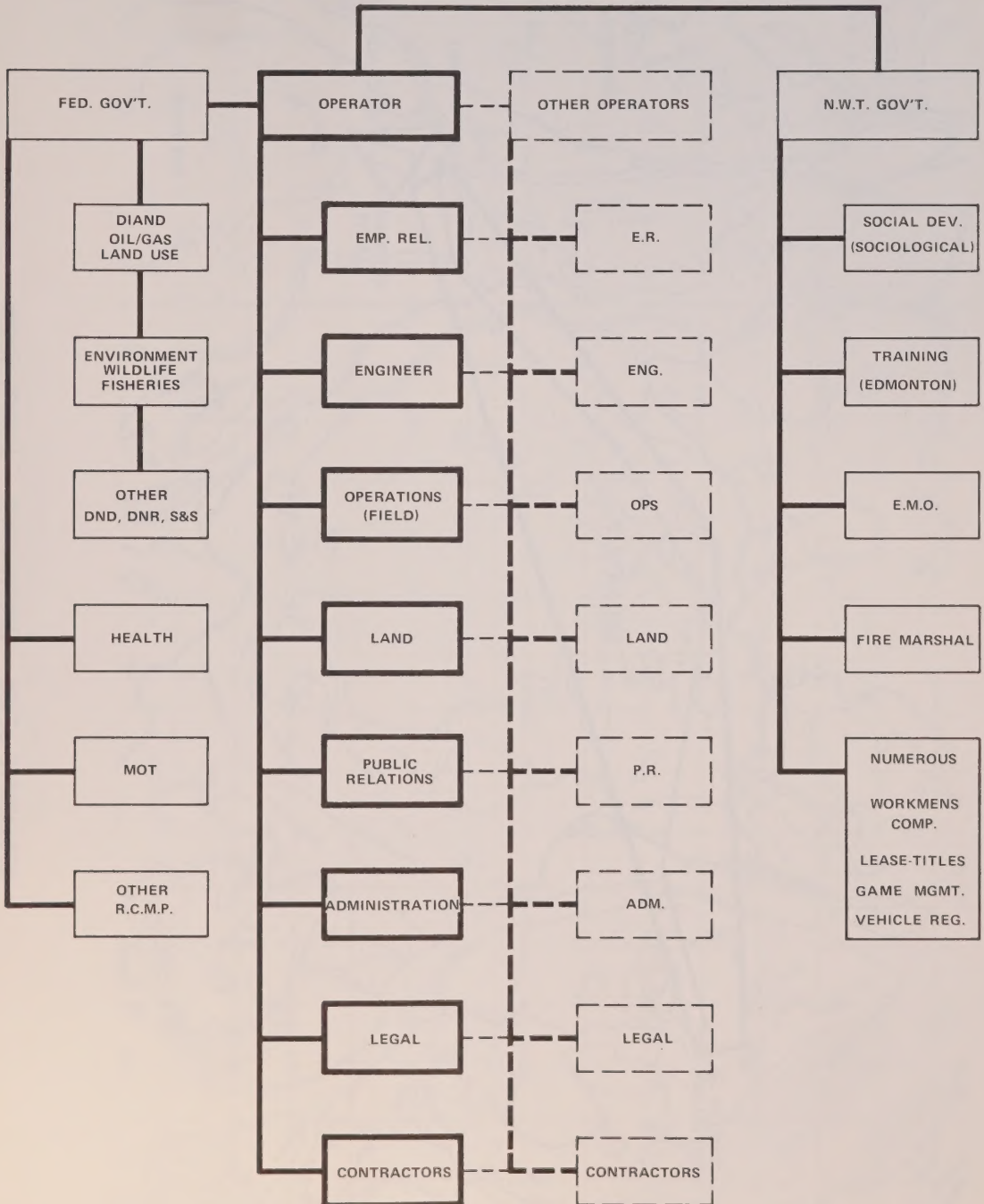


NOTE:

IN THE EVENT OF A HYDROCARBON SPILL OR "BLOWOUT", THE CONTINGENCY PLAN PROVIDED BY THE OPERATOR "OIL SPILL CONTINGENCY PLAN" WILL BE EFFECTED'

FIGURE 26

PROPOSED CONTINGENCY PLAN RELATIONSHIP



SECTIONAL PLAN NIGLINTGAK – TAGLU AREA

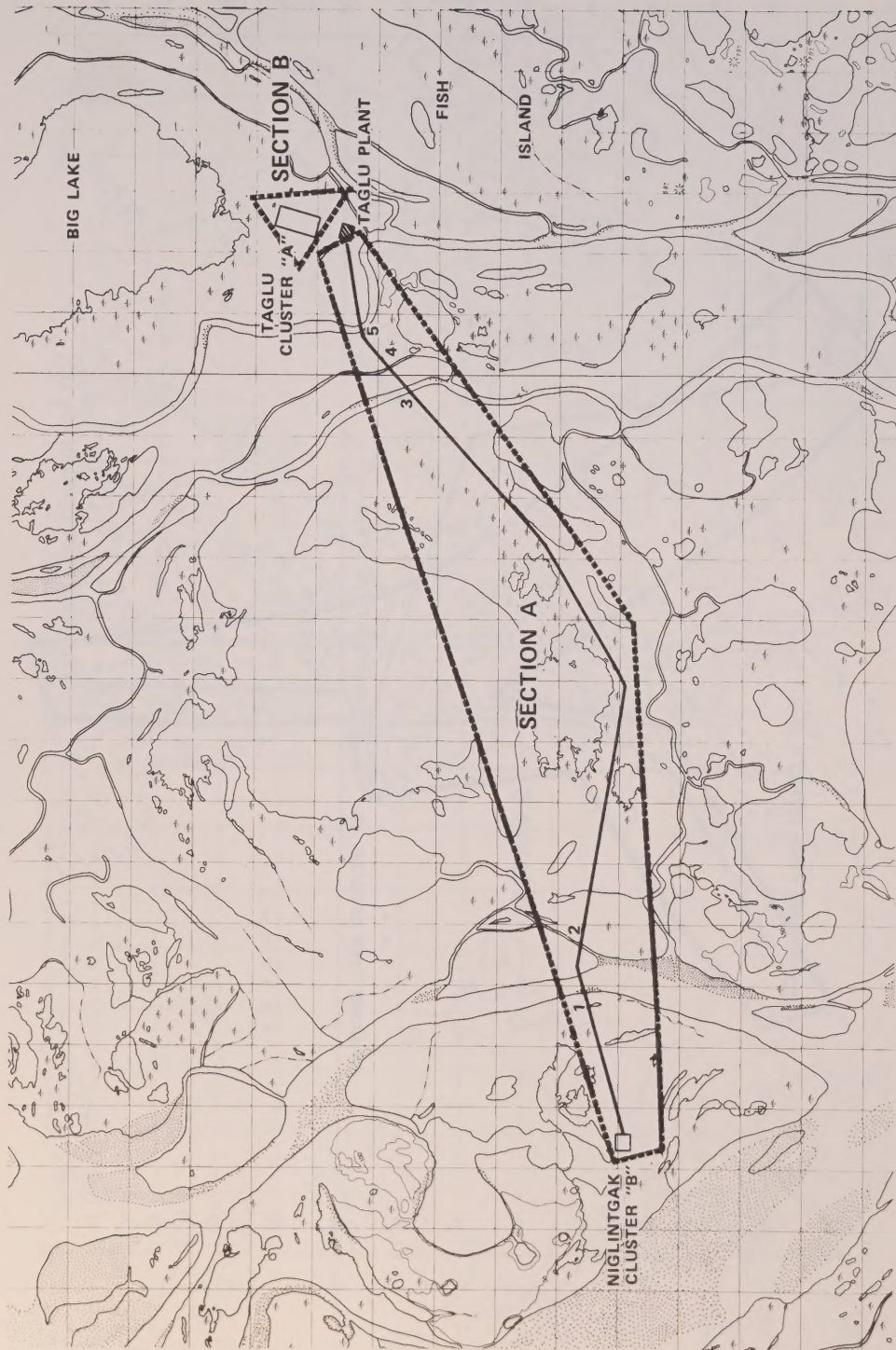


FIGURE 28

SECTIONAL PLAN PARSONS LAKE AREA

